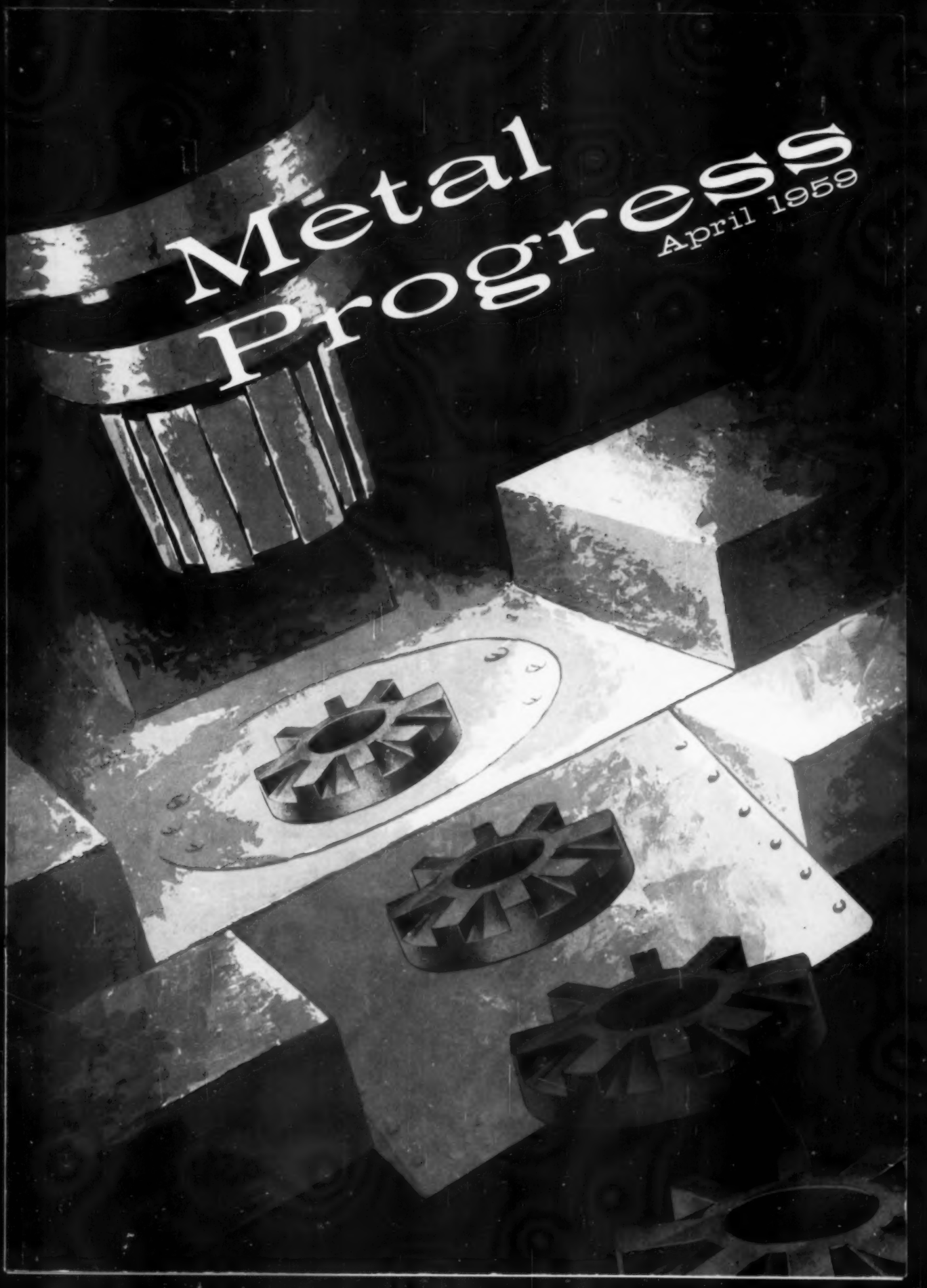
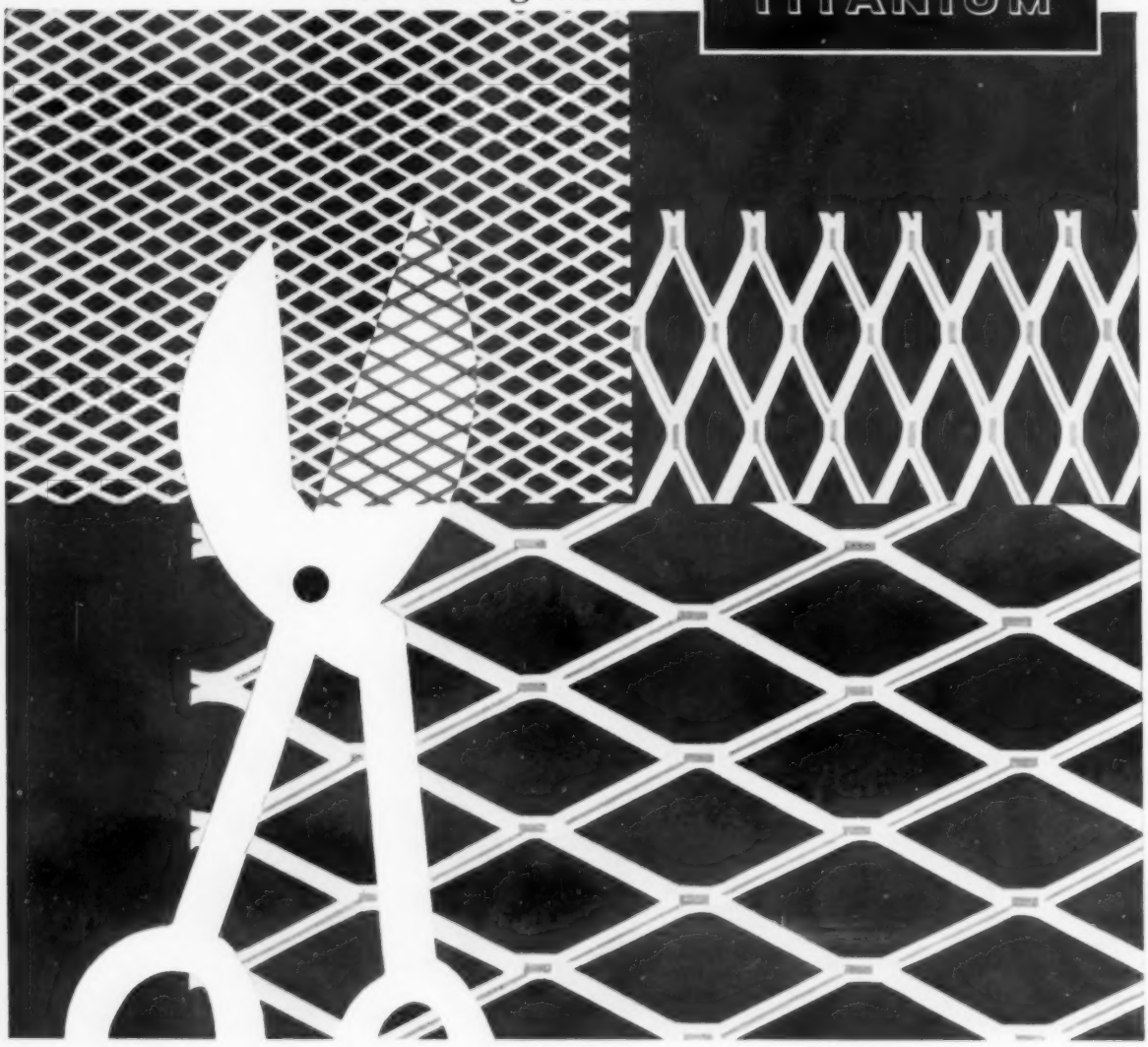

Metal Progress
April 1959

Cost cutting ideas in **TITANIUM**



EXPANDED TITANIUM SHEET

"opens up" new savings in corrosive plating applications

Now, cost-saving applications for titanium take another important step forward. Expanded titanium sheet, recently introduced by Mallory-Sharon, offers interesting possibilities for use in the plating and chemical processing industries.

Dip baskets

Filters

Its high corrosion resistance makes it ideal for use in acid plating, acid dipping baskets, and in protection shields for immersion heating electrodes. The new material is available in gauges from .015" to .125", from ⅛" to 1½" diamonds, and in standard 48" x 96" sheets.

Protective shields

Expanded titanium sheet is now available in production quantities. Prices vary with gauge and strand widths. For further information, write for Technical Data Sheet.

MALLORY SHARON

MALLORY-SHARON METALS CORPORATION · NILES, OHIO

Metal Progress

April 1959 . . . Volume 75, No. 4

Cover design, by FLOYD E. CRAIG, *Metal Progress* art director, ties in with the "Powder Metallurgy Today" feature on p. 105 and 113.

A Managing Director for American Society for Metals 96-E

Engineering Articles

Tough Ship Plate, by William J. Harris, Jr., and Clyde Williams 66

A review of the enormous amount of work done since 1946 by the Ship Structure Committee leads to the conclusion that a vanishing number of failures need be expected in normal service of welded ships properly designed and constructed of steels meeting the revised specifications of the American Bureau of Shipping. (Q26s, T22g; ST, 4-53, 7-51)*

Fuel for the Atomic Engine, by B. Lustman 72

The fuel in the Shippingport atomic power plant consists of long metallic elements of highly enriched uranium, arranged in a hollow square which encloses and is surrounded by a "blanket" of natural uranium oxide. This article describes the work necessary to prove the suitability of this material and the fabrication methods (T11g, 17-57, R4; U)

Automatic Controls for Protective Atmospheres, by William C. Diman 79

Automatic proportioning valves, dew point indicators, flash back arresters, blow offs, flame controls, temperature regulators, pressure regulators, alarms, flowmeters and system interlocks are assembled according to the needs for protecting workmen, equipment and material in process. (W28q, X7, X13f)

Control of Magnetic Particle Testing, by J. W. Schweikert 84

Suspensions can be tested in 2 min. with a hand-operated centrifuge; the settling test outlined by most specifications lasts 30 to 60 min. This new method, easily managed by machine operators, makes it simple to keep magnetic particle baths within specification limits. (S13j)

Surface Fatigue of Carbo-Nitrided Steel, by G. W. Powell, M. B. Bever and C. F. Floe 88

Observations supplementing previous work by these authors indicate that carbo-nitrided cases must be thick enough to withstand service-induced stresses. Otherwise, the mechanical properties of the core, which are lower, will determine the fatigue life. (Q7, J28m; ST)

Titanium Alloys Today – How Commercial Alloys Compare, by Paul D. Frost 91

Divided into alpha, alpha-beta, and beta types, commercial titanium alloys have widely varying properties. Alpha alloys have high strength and good oxidation resistance at elevated temperatures, but cannot be heat treated readily. Alpha-beta and beta alloys respond to heat treatment and are more formable than alpha alloys. Research and development programs will broaden applications. (Q-general, 17-57; Ti-b)

Problems of Aircraft and Missile Production Spur Successful Western Metal Congress 96-F

Technical sessions on selection criteria for materials; forum discussions on carbon control in heat treating and hydrogen embrittlement; panel discussions on vacuum melted alloys and reduction of warpage. Other topics were welding of high-strength metals for pressure vessels, radiation effects on materials, inspection methods for honeycomb, advances in ultrasonic and eddy current testing, explosive forming. (A-general)

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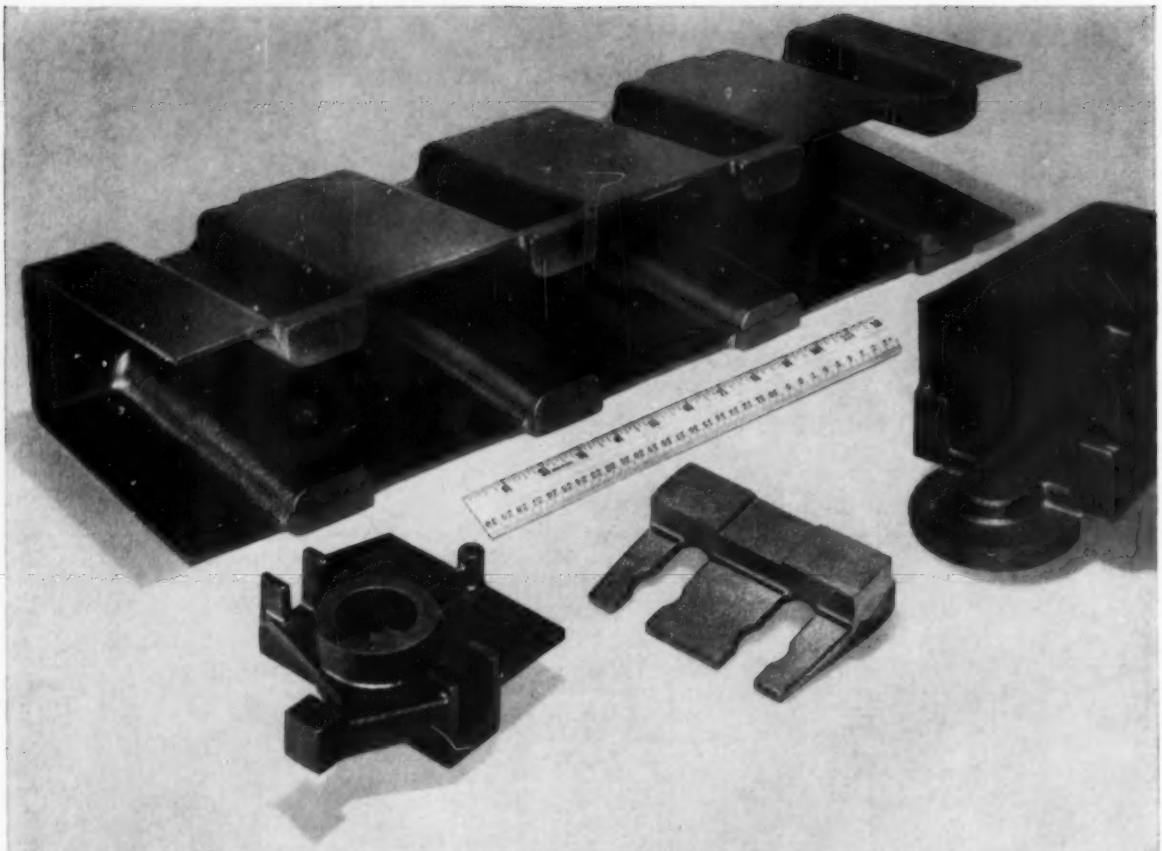
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



Electro-Alloys shell molded heat- and corrosion-resistant castings open a new range of applications where high dimensional accuracy, reduced machining cost, and superior finish are needed. Write

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for technical information.

AMERICAN Brake Shoe COMPANY

Fabricating and Finishing Toolsteels for Aircraft Parts, by P. E. Ruff 97

H-11 maintains high strength at elevated temperatures. Formability is similar to that of 4130, and weldability is like that of 4340. Parts are limited to a 4-in. thick section to obtain through hardening on air cooling. Most parts require coatings for corrosion protection. Specific procedures for processing H-11 are given. (Q-general, J-general, G17k, K9s; TS, SGA-h)

Powder Metallurgy Today

How to Do More With Prealloyed Powders, by W. L. Batten 105

These powders are produced from molten alloys, and compacts have properties of the composition within limitations of the density achieved. Parts made from alloy steel powders, such as gears and cams, can be heat treated to high strength. A variety of stainless steel and special powders are useful in corrosion resisting, high-temperature and electrical applications. (H-general, H12n; AY, SS, TS)

Extruding Metal Powders, by Eric Gregory 113

By modifying conventional extrusion methods, powders can be extruded in long bars with cross sections of varying complexity. In many instances, density is close to 100%. Still largely in the experimental stage, powder extrusion methods are used to produce materials with good elevated-temperature properties. They are also being considered for making certain atomic reactor fuel elements. (H14k)

Critical Points

"Unbreakable" Ships in a Hurry? 65

Book Review

Study of Materials Based on Their Structures, Reviewed by Jack Washburn 88

"The Science of Engineering Materials", edited by J. E. Goldman, relates material properties to structure, and in so doing shows why so many experimental materials have been transformed into useful products in the past 50 years.

Data Sheet

Hardenability Bands for Steels 8822-H to 9850-H 96-B

Short Runs

Brazing Gear Shift Levers 103

X-Ray Dimension Gage 104

Digest of the Month

Weldability of High-Strength Steel 128

The 1958 Adams Lecture of the American Welding Society by Ernest F. Nippes summarizes work done at Rensselaer Polytechnic Institute over a period of 14 years, aimed at predicting proper welding conditions on the basis of heating and cooling cycles.

Metals Engineering Digest

Aircraft Quality Steels 135

Meticulous care in every phase of melting and pouring is required for high quality in ultra high-strength steels.

Use of Vibration in Casting 140

Promotes degassing and grain refinement and improves casting detail.

Improvement of Castings by Press Forgings 147

Molybdenum Welding 158

Use of a consumable electrode improves ductility of the weldment but introduces additional problems.

Spectrochemical Analysis Using the Quantovac 172

Surface Rolling to Increase Fatigue Strength 174

Clad Steels for Nuclear Applications 178

Economies in heavy-walled piping are provided by a stainless, nickel or Monel cladding bonded to a carbon or alloy steel backing.

Brazing Alloys Resistant to Oxidation and Sodium Corrosion 182

Unusual Stud Welding Application 190

Improves the reliability of a vibrating wire strain gage.

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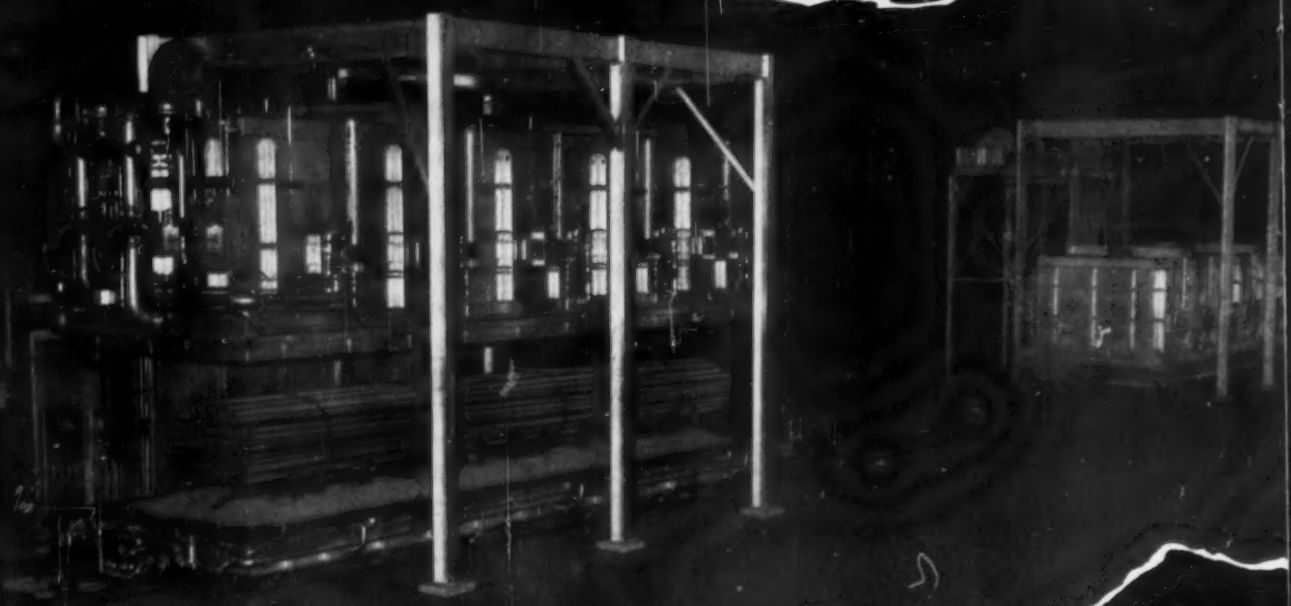
Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices 7301 Euclid Ave., Cleveland 3, Ohio. Entered as second class matter at the Post Office in Mt. Morris, Ill. Vol. 75, No. 4, April 1959. Copyrighted 1959 by the American Society for Metals.

Lee Wilson

...BRINGS BETTER CONTROL TO MERCHANT BAR ANNEALING



The finest control of merchant bar annealing yet known has been achieved with the new Lee Wilson Bar Annealing System, with multiple-zone control in the furnace and with radiant tube base heating with its control interlocked with the furnace zones.

These new furnaces process anneal, spheroidize and lamellar anneal to uniform physical properties because the heat is applied more uniformly and controlled with greater precision. Proper atmospheres protect against decarburization.

Shown above is the new Lee Wilson installation at a plant of a large Eastern producer of high carbon, alloy and stainless merchant bar and coils.

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Press Breaks...

One sometimes longs for the apparent simplicity of the old days (well, a century ago). For example, there were then two kinds of engineers, military engineers and civil engineers. Even at the turn of the century there were no metallurgical engineers; they were either mining engineers or chemists. Also in those halcyon days physics consisted of matter (liquids, solids and gases), force, and motion (sound, heat, light), magnetism and electricity; nothing about ordered, disordered or missing atoms, for example, which bother today's physical metallurgist.

So – one wonders (if he is Editor-in-Chief of *Metal Progress)* just what *is* a metallurgist, or a metallurgical engineer, or (as our friends in the advertising department prefer) a metals engineer? What is metallurgy? It ought to be defined, for it should define the editorial scope of this journal. Here is a try:

"Metallurgy means the arts and sciences underlying the production of any metal from its ore or concentrate; its refining, alloying and manufacture into mill shapes including foundry and forge; machining, forming or shaping operations where quality of metal or tool is critical; heat treatment; welding; finishing for protection. It includes research into and production of conventional metals and alloys and new variations to meet special services. It includes data on mechanical and physical properties, and on performance in ordinary, corrosive or hot environments. It includes equipment and methods for inspection and research."

Sometimes, in a mood of despair, an editor swears that technical writings get worse by the minute. He is spending too much of his life converting such sentences as (don't laugh, this is an actual example) "It was necessary to develop a fabrication process which could permit the fabrication of . . . in the year available schedular-wise" into something more direct; such as "In a year's time we had to find suitable fabrication processes and make . . ." It is a continual struggle to keep as many plain words on the page as possible, along with a few of the necessary special terms in scientific, engineering and technological jargon.

Of course there are excellent books on composition and the use of simple words, but it is too much to expect an engineer to read them and practice their precepts. He didn't have time for such things in college (even though his success in later life may well depend on his ability to write his ideas clearly). Unfortunately, too few have been raised in families where the Bible was read aloud every evening, and Shakespeare was regarded as music. But one thing we do wish our contributors would do and that is to write as they would talk! One can hardly imagine anyone saying such a word(?) as "schedular-wise" without stumbling or blushing.

Fortunately for the relationships between editors of engineering journals and their contributors (and we do love them), the latter usually agree that plain words are fine when they see them on paper. To those few who seem to object we recommend that they go to the public library and compare Macaulay's "History of England" with Gibbon's "Decline and Fall of the Roman Empire". The first is a fine example of plain Anglo-Saxon talk; the second of polysyllabic Latin rotundity.

The Editors

BRUSH BERYLLIUM BULLETIN

application and fabrication news

PROGRESS REPORT ON BERYLLIUM ROLLING.

Pilot production phase has been reached in an AIR FORCE-sponsored program of hot-rolling beryllium. Concurrent BRUSH-sponsored research is making available sheet of aircraft size with GUARANTEED MINIMUM MECHANICAL PROPERTIES.

SHEET BERYLLIUM FOR MISSILES.

BRUSH has recently completed fabrication of missile components from hot-rolled sheet. Equipment and techniques used were slight modifications of standard methods used for other engineering materials. Use of these standard sheet forming and joining methods means lower fabricating costs.

SPACE VEHICLES TO USE BERYLLIUM "HEAT SINK."

Many of the space vehicles now on design boards specify beryllium components in areas subjected to high heat loads. In beryllium, high melting point, high thermal conductivity and high heat capacity are combined for optimum "heat-sink" properties. The ability of beryllium components to withstand extremely high heat loading has been proven in exhaustive static and flight tests conducted by aircraft industry leaders.

BRUSH BERYLLIUM maintains a staff of qualified application engineers to act as consultants to space study groups and equipment contractors designing with beryllium. These men, experienced in the development of beryllium technology by BRUSH, keep in constant touch with the latest developments in laboratory research and production standards. Complimentary design assistance is available on request.

NEW BeO LITERATURE.

For those interested in application of BERYLLIUM OXIDE, BRUSH has compiled available data on the new, high-purity, sinterable oxide, UOX. For copies, write to:

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Printed by Kable Printing Co., Mt. Morris, Ill.

Subscription $9.00 a year in U. S. and Canada; foreign $15.00. Single copies $1.50; special issues $3.00. Requests for change in address should include *old* address of the subscriber; missing numbers due to "change of address" cannot be replaced. Claims for nondelivery must be made within 60 days of issue. No claims allowed to overseas subscribers.

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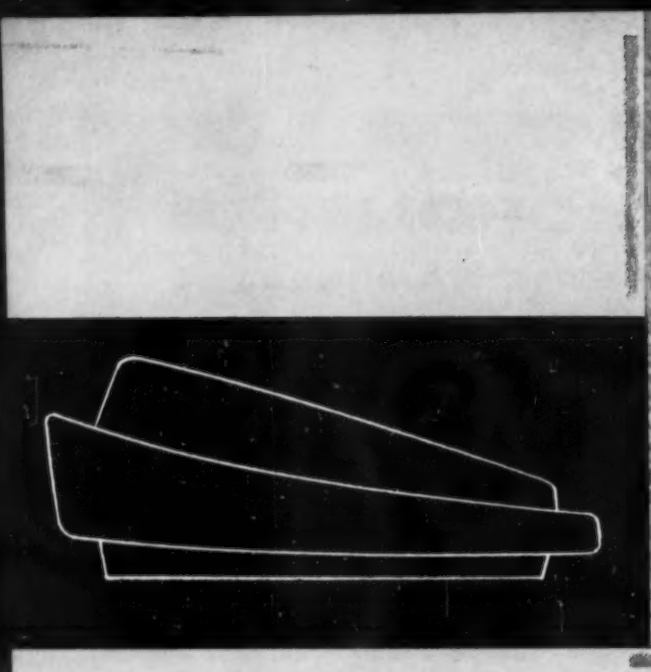
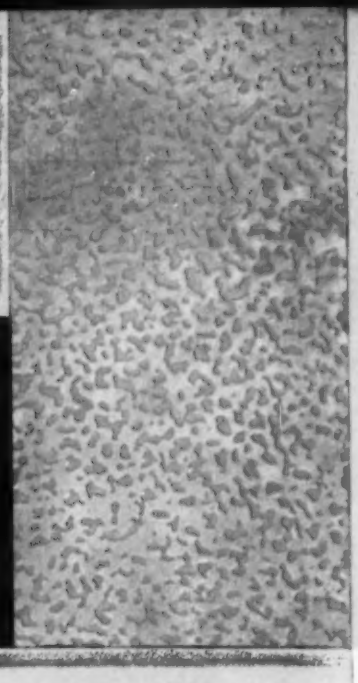
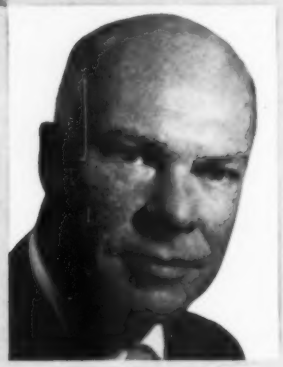




Peter Schladermundt, A.I.A., A.S.I.D., P.D.C., for 25 years a leading designer of many of America's foremost industrial products. Formerly associated with Norman Bel Geddes and other designers and architects on such projects as General Motors "FUTURAMA" and the design of Rockefeller Centre. Presently heading his own firm specializing in all types of design service to industry. Recently designed the Trade Fairs for the United States Government Department of Commerce in Milan and Paris.



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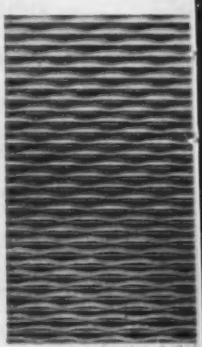
It's the kind of forward thinking that has made Sharonart the most popular material of its kind. Literature and information available from the Sharon salesman in your area or by writing direct to *Sharon Steel Corporation, Sharon Pa.*



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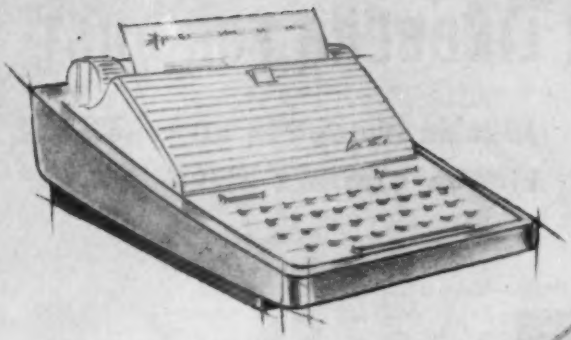

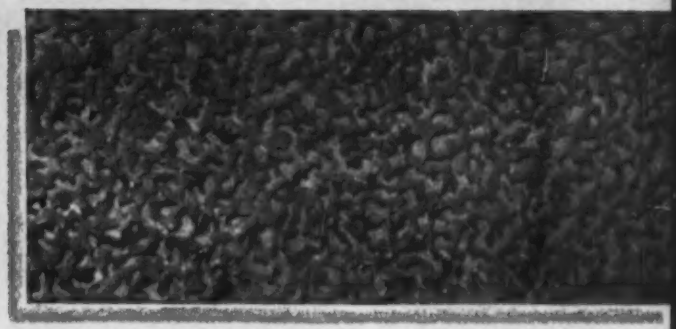

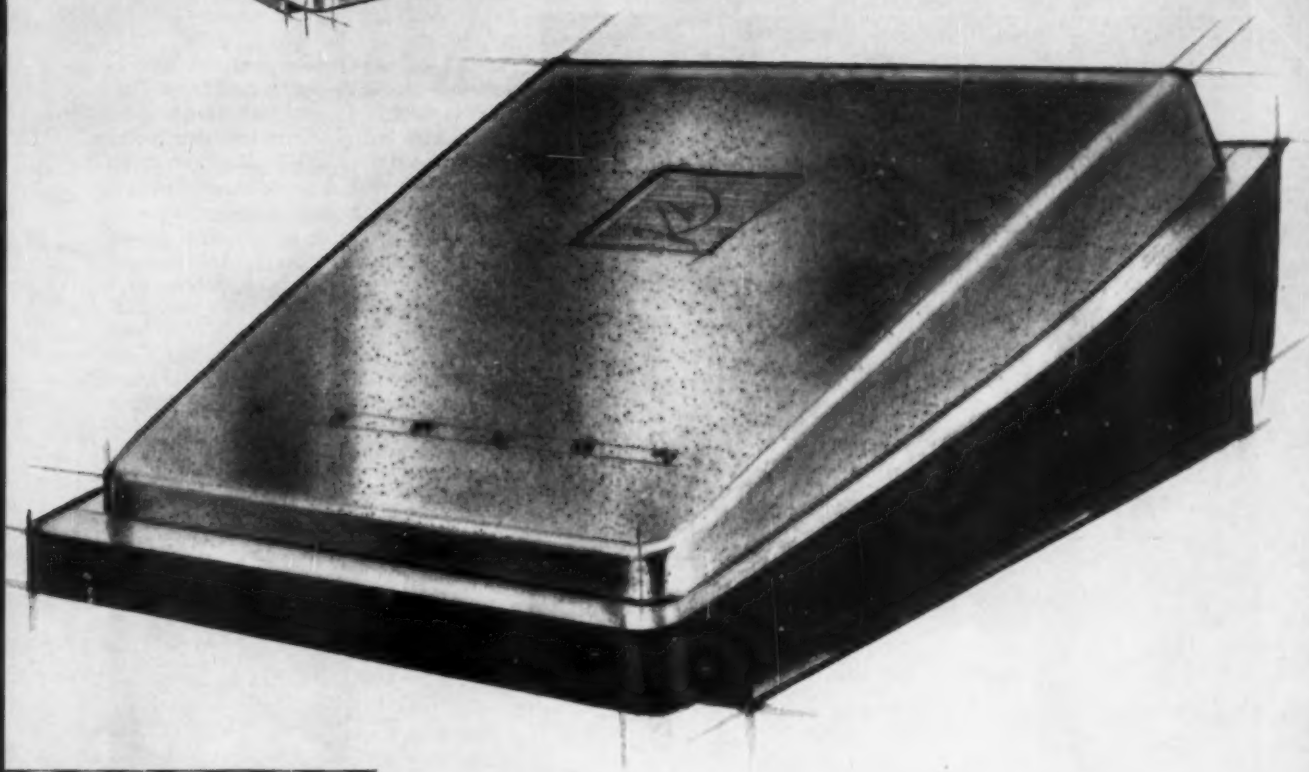

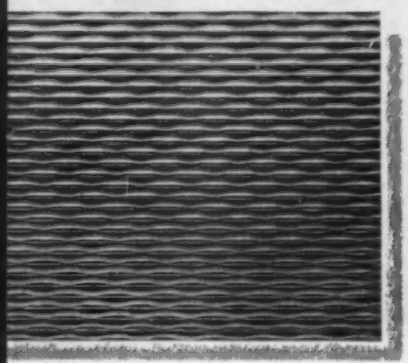

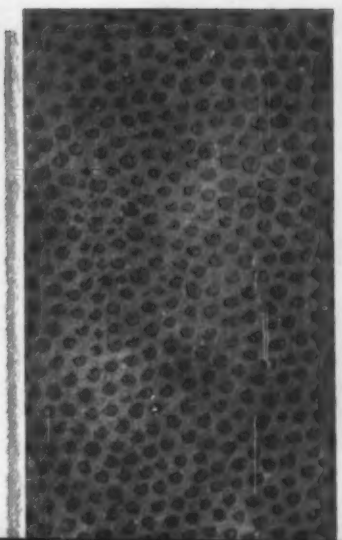

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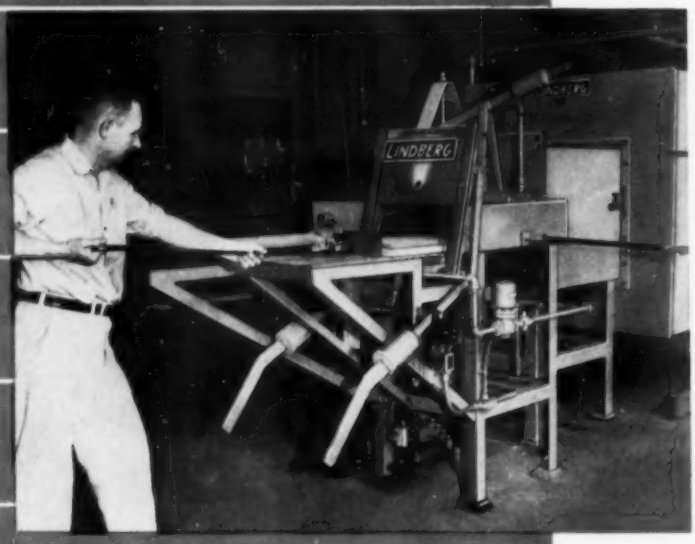
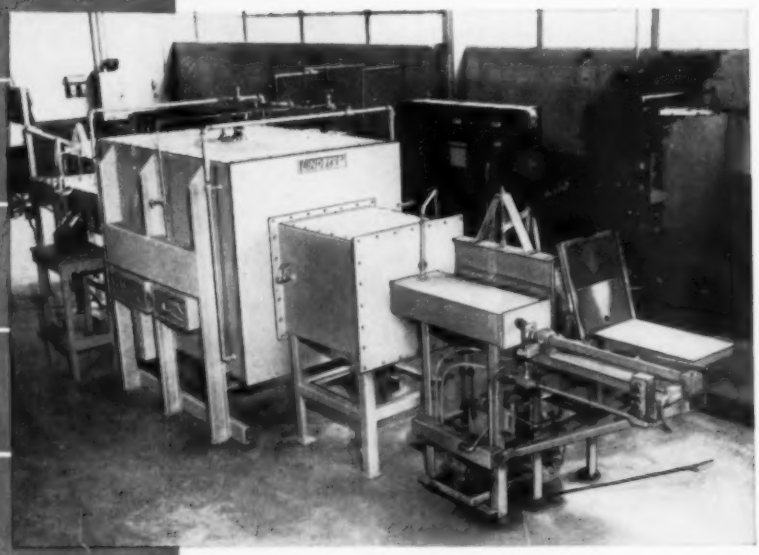


A new Lindberg development, this Molybdenum Element Atmosphere Pusher Furnace is designed with high temperature refractories suitable for low dew point without need for a muffle. It is now being used for sintering stainless steel compacts in hydrogen or dissociated ammonia. Ammonia dissociator and control panels are shown at the right of the furnace below. In this installation hydrogen supply cylinders are located outside the building. Furnace provides side loading and discharge ports with purging chambers. Work trays, ceramic slabs or molybdenum boats, move through the furnace by hydraulic pusher. If you have a sintering or brazing problem why not talk it over with Lindberg.



Type MOP-12367-A60C Molybdenum Element Atmosphere Pusher Furnace. Maximum Temperature 3000° F. 60 KW input. 12" wide, 30" long, 7" high. 66" cooling chamber, 36" long preheat chamber.

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FOR SINTERING YOU THE RIGHT FURNACE

industrial heating equipment; sintering and brazing furnaces

This Hand Pusher Batch Type Furnace

is used for small production lots and experimental sintering. It is an all-purpose unit for operation from 1300°F to 2500°F. Made in various sizes for sintering from 25 to 300 pounds per hour.

This Mesh Belt Continuous Type Furnace

is a popular sintering furnace for small light parts in copper, bronze, brass or steel with a temperature range from 1300°F. to 2100°F. It can be used for low temperature silver brazing, bright annealing, as well as sintering of powder metals. Production ranges up to 500 pounds per hour.

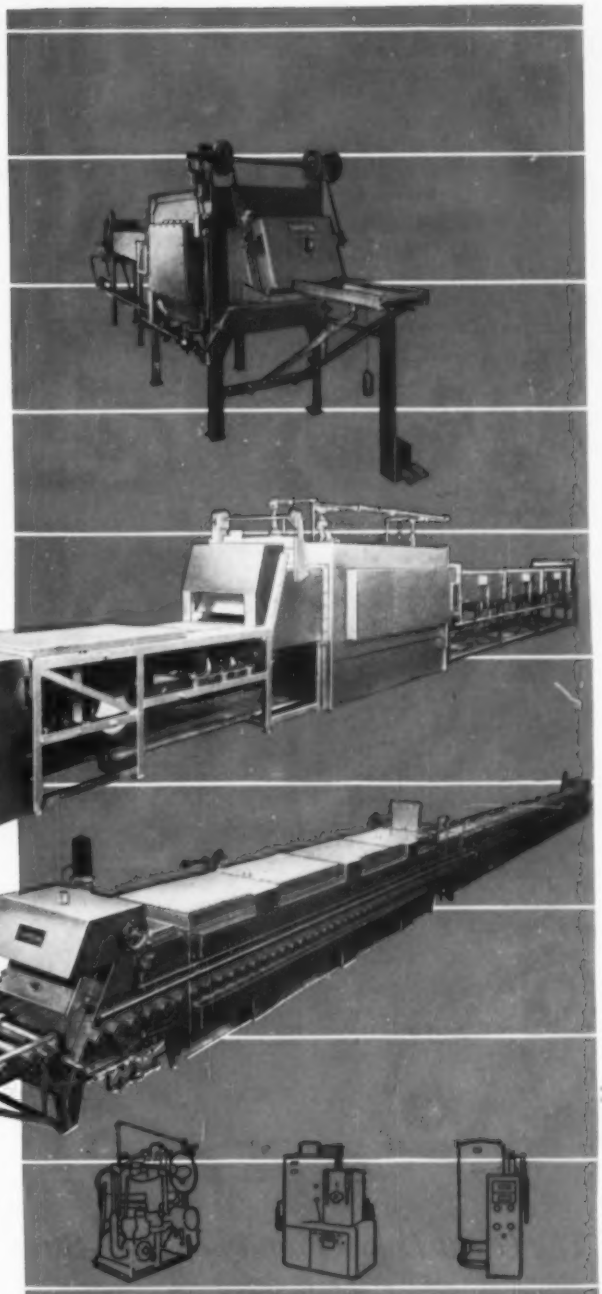
This Roller Hearth Continuous Type Furnace

is especially designed to handle heavier loads up to 2200 pounds per hour. It has an effective temperature range from 1300°F. to 2100°F. It can be used for bright annealing, low temperature silver brazing as well as sintering of powder metals.

Atmosphere Generators

To obtain the best work from any sintering furnaces, the proper atmosphere is required. The atmosphere generators described here provide the proper atmospheres recommended for use with Lindberg Sintering Furnaces.

If you have a sintering or brazing problem why not talk it over with Lindberg. Just get in touch with your nearest Lindberg Field Representative or write us direct.



1. The HYEX Generator produces atmosphere composed of approximately 4% carbon dioxide—18% hydrogen—12% carbon monoxide and 66% nitrogen.

2. The HYEN Generator produces a neutral atmosphere composed of approximately 21% carbon monoxide—40% hydrogen—38% nitrogen and 1% methane.

3. The HYAM Generator produces atmosphere composed of approximately 75% hydrogen and 25% nitrogen.

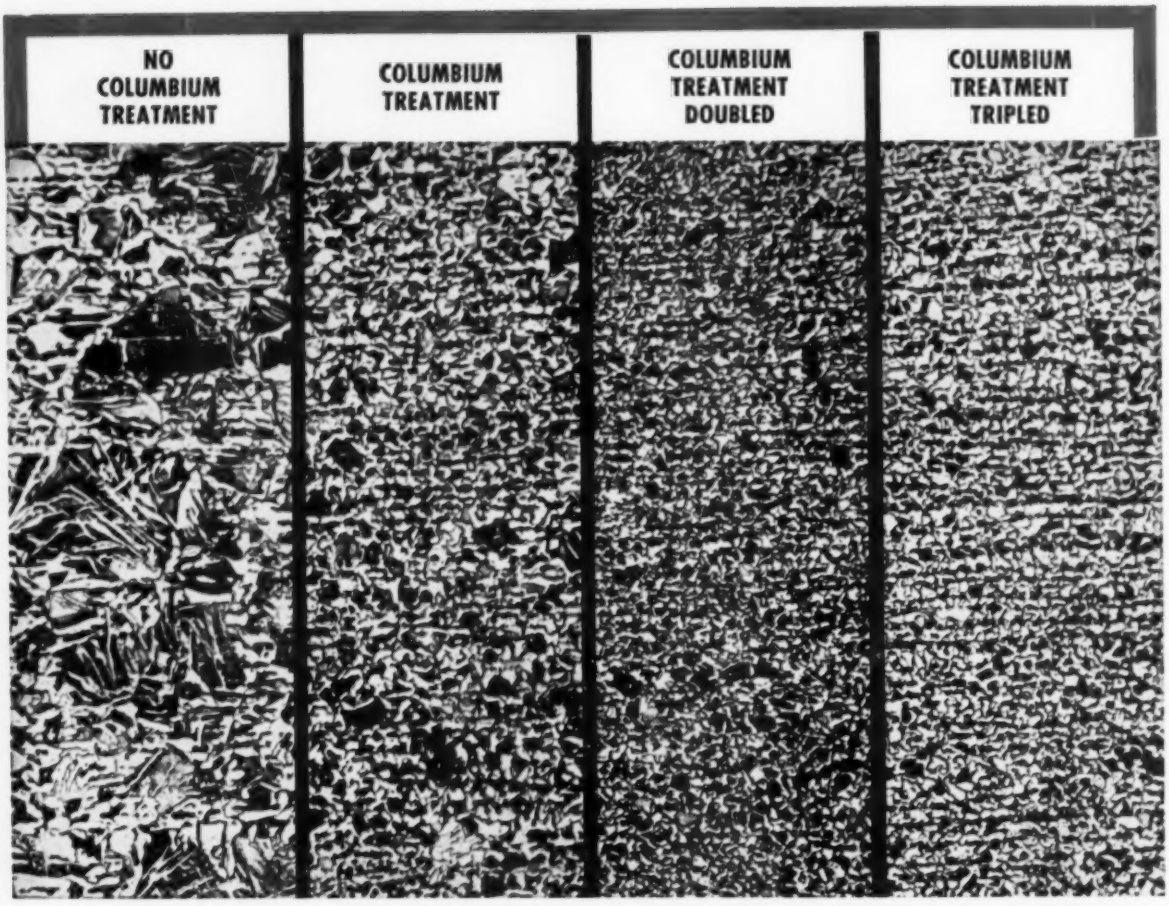
LINDBERG

ENGINEERING COMPANY

Los Angeles Plant: 11937 S. Regentview Ave., at Downey, Cal.

2448 W. HUBBARD ST., CHICAGO 12, ILL.

HOW GREAT LAKES



Composite of photomicrographs made from the same heat of mild carbon steel shows the effect of varying columbium treatments on the grain structure of the steel.

The Great Lakes Family of High-Strength Steels

N·A·X FINEGRAIN STEEL

Lets you design superior performance, longer life and less weight into your product. Many diversified applications.

N·A·X HIGH-TENSILE STEEL

Offers all the characteristic features of N-A-X Finegrain, plus greatly enhanced resistance to atmospheric corrosion.

GLX W

A series of fine grained, mild carbon steels. They have unusually high strength, toughness and weldability.

N·A·X N-A-XTRA STEELS

Quenched and tempered steels of excellent weldability and toughness, with yield strengths from 80,000 - 110,000 psi.

N·A·X HIGH MANGANESE STEELS

N-A-X High Manganese and High Manganese Special Killed. These steels give yield strengths up to 50,000 psi.

STEEL CORPORATION'S NEW GLX-W STEELS GIVE ... HIGH STRENGTH TOUGHNESS REDUCED COSTS

Key to the success of Great Lakes' new GLX-W Series of steels is the fine grained internal structure produced by treatment with columbium. This grain refinement also contributes to ductility. And in addition, the GLX-W Series' low carbon and manganese content assures excellent weldability with freedom from underbead cracking under all conditions.

COST AND WEIGHT SAVINGS

Where design permits the replacement of carbon steel with GLX-W steels, weight savings of 20 to 35 per cent, and cost savings of 10 to 25 per cent can be realized. When replacing alloy steels the cost savings can range from 25 to 35 per cent. These steels feature higher yield strengths, greater tensile strengths and increased toughness without costly heat treatments or extensive alloy additions.

The GLX-W Series is so priced that substantial cost reductions can be obtained by weight reduction over mild carbon steel. Cost reduction can also be obtained over alloy steels because of the lower price of GLX-W steels.

MANY USES FOR GLX-W STEELS

GLX-W steels are especially recommended for a broad range of applications in mobile equipment and pressure vessels, as well as the transportation and construction fields.

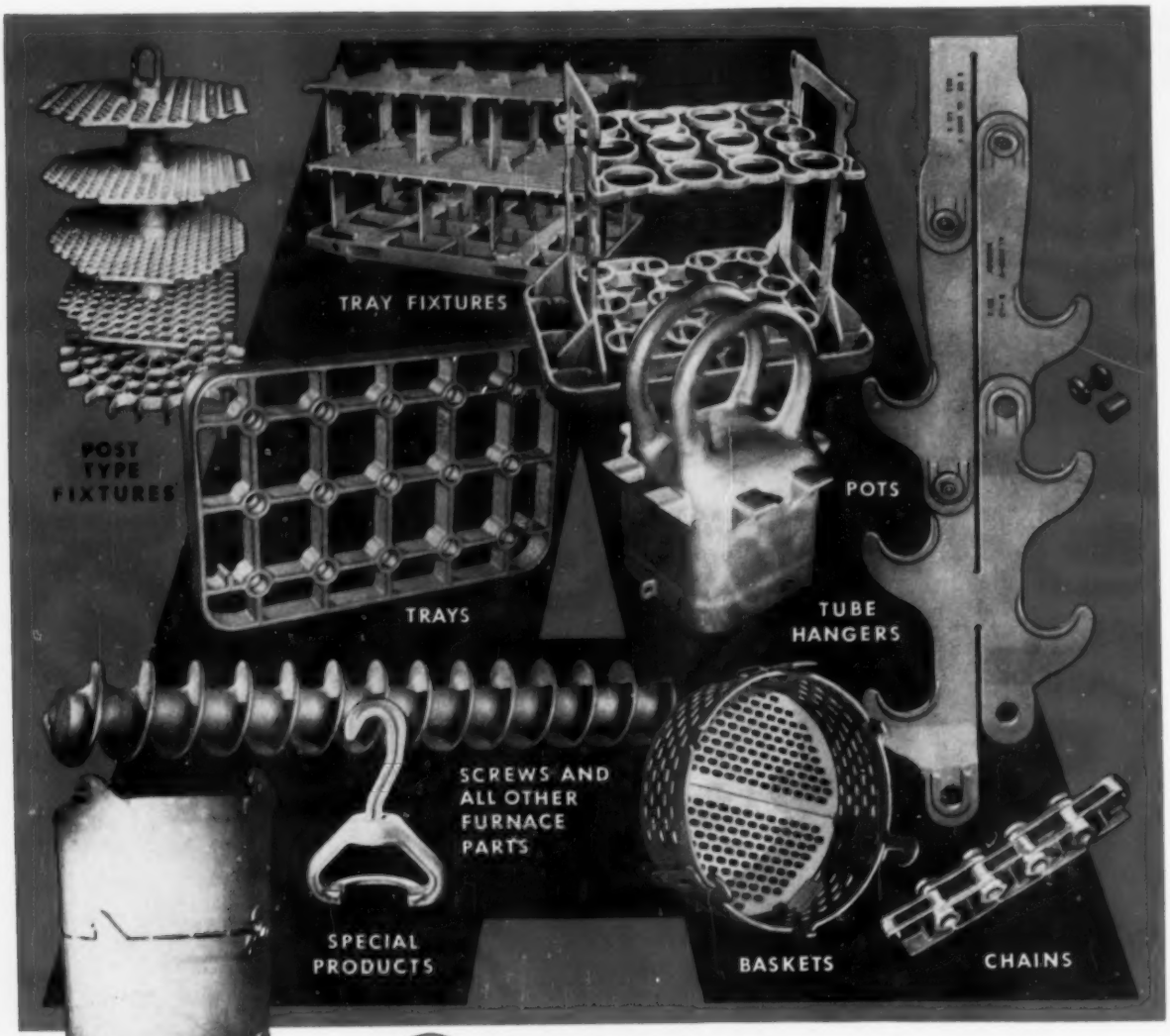
STRONGER AND TOUGHER

GLX-W steels are stronger and tougher than ordinary mild carbon steels and in some applications can do the job now being done by the more costly alloy steels.

GLX
W

For additional technical information about these economical GLX-W steels write

Product Development Division, Dept. B-1
GREAT LAKES STEEL CORPORATION
Detroit 29, Michigan • Division of
NATIONAL STEEL CORPORATION



"A" MEANS ACCOLOY–

THE TRADEMARK OF LEADERSHIP IN HEAT AND CORROSION RESISTANT ALLOY CASTINGS

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

AEC ENGINEERING GIVES Better Service ON HIGH TEMPERATURE TOOLING

"Custom Engineered" PRODUCTS FOR ALL HEAT TREATING and OTHER HIGH TEMPERATURE OPERATIONS

ENGINEERING MAKES THE DIFFERENCE

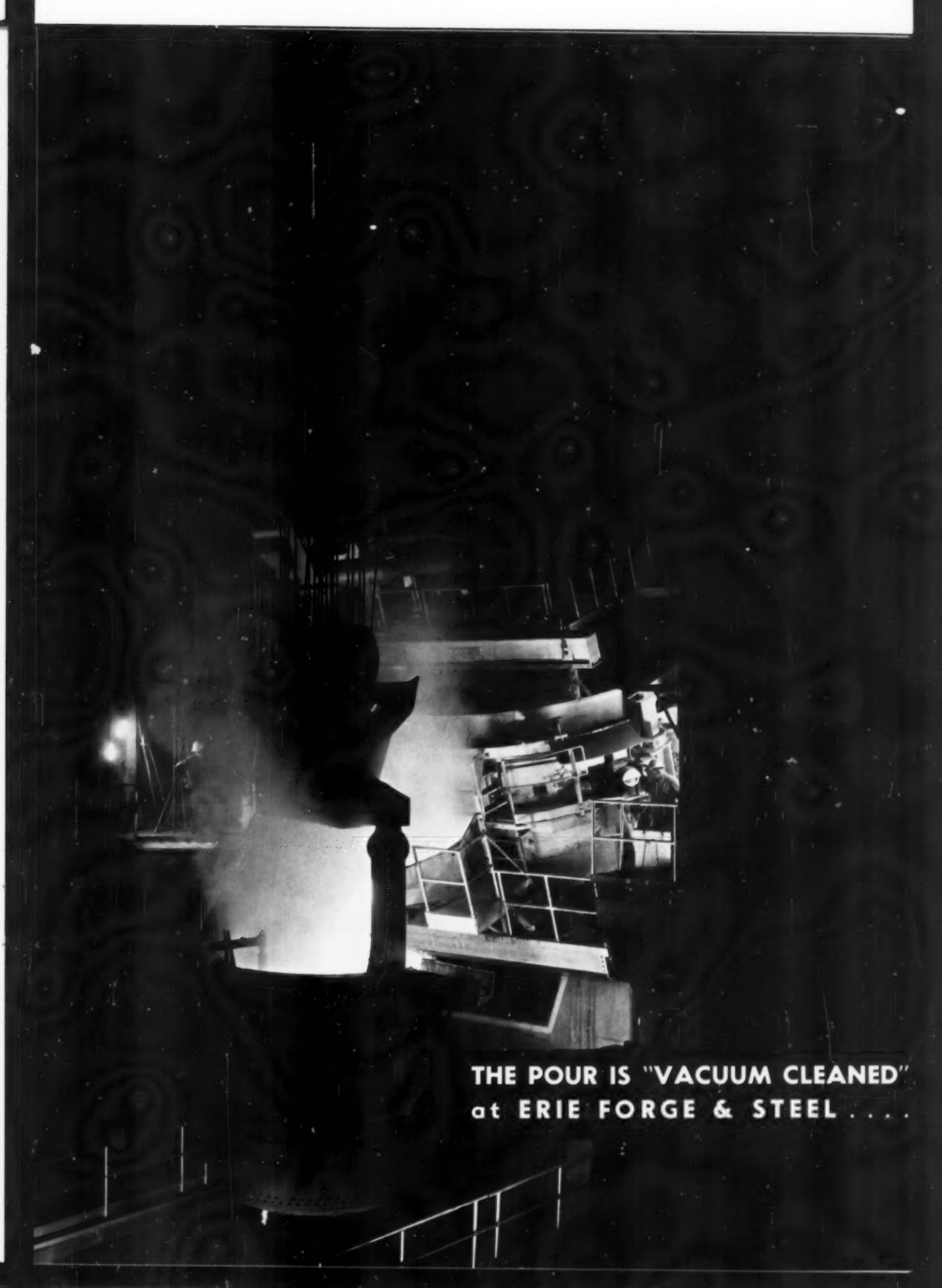
The examples shown—and hundreds of others—have all given superior service. High integrity products are assured by component design, by use of proprietary casting technology, and in preferred metallurgical structure in relation to service stresses. Production utility is assured by our unequalled background on high temperature mechanisms and in heat treating processes.

CONTACT OUR REPRESENTATIVES—OR WRITE US DIRECTLY

ALLOY ENGINEERING & CASTING CO.

1700 W. WASHINGTON ST., CHAMPAIGN, ILL. TELEPHONE FLEETWOOD 6-2568

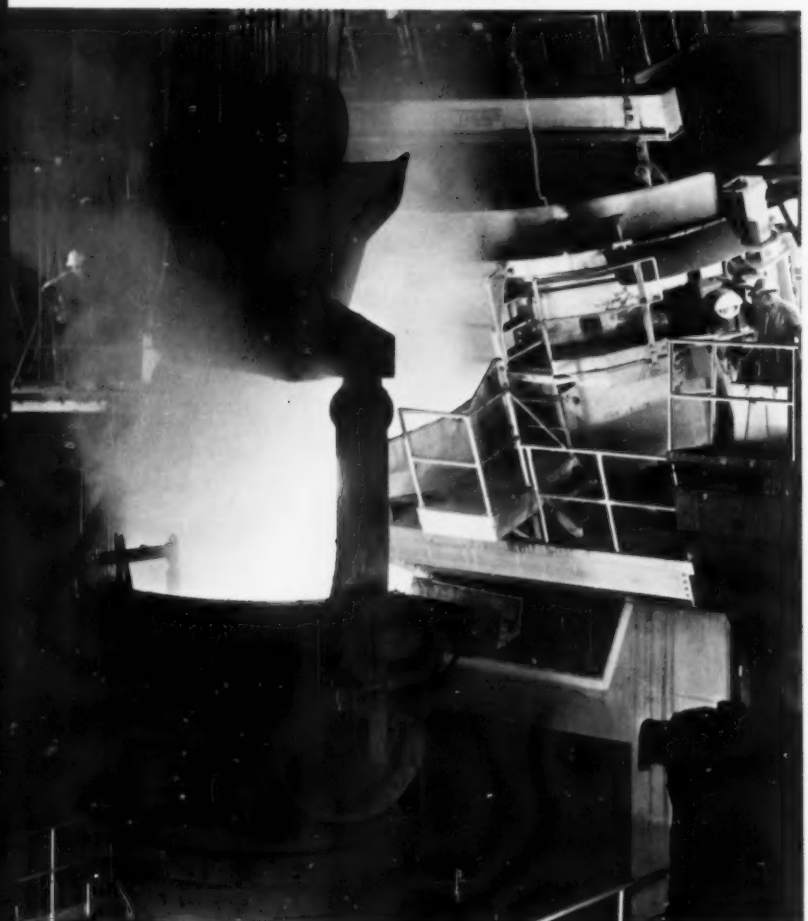
ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS


THE POUR IS "VACUUM CLEANED"
at ERIE FORGE & STEEL . . . .

75 TON ELECTRIC FURNACE

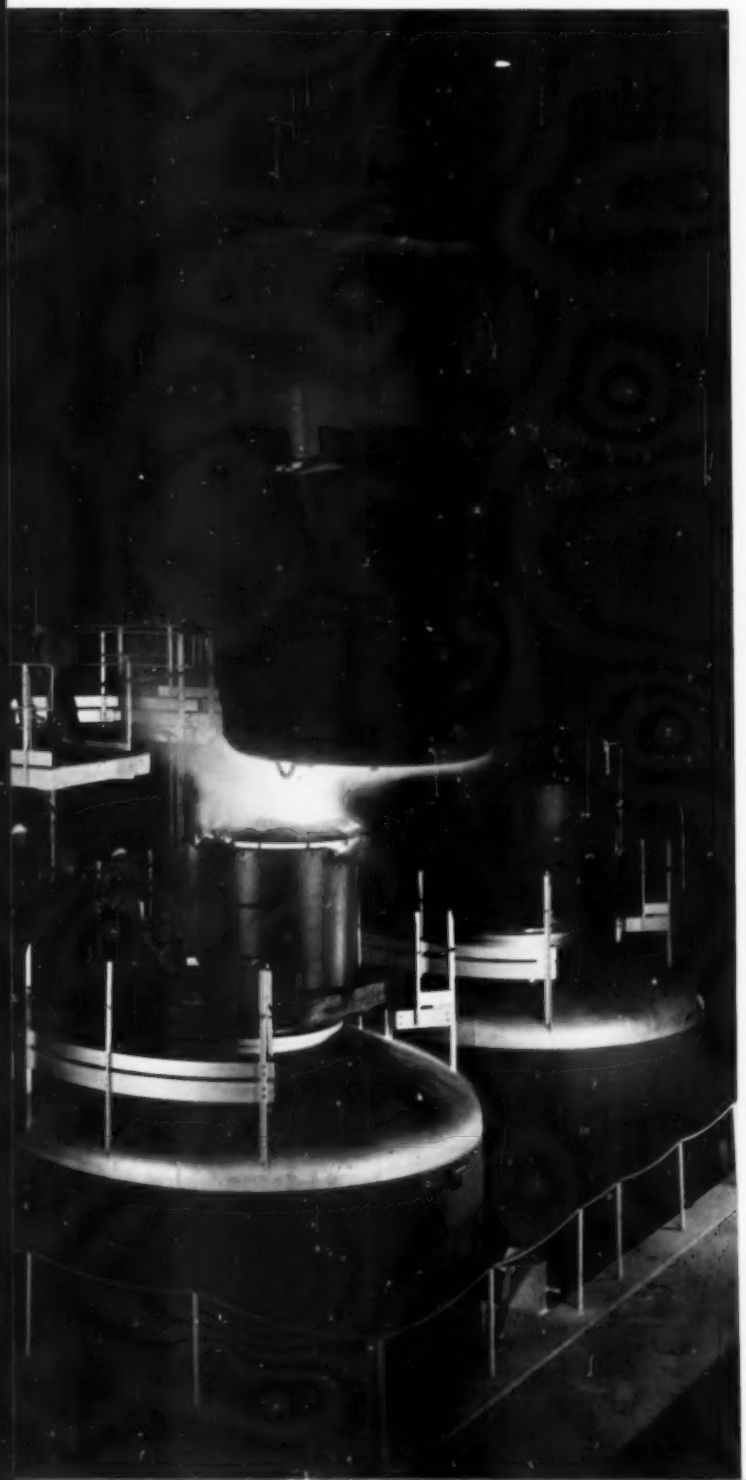
Charging Operation

Color Photography by Joseph Balbuza



Pouring Operation

ELECTRIC FURNACE STEEL teams up with VACUUM CASTING at Erie Forge & Steel



Sired by The Electric Furnace Out of the Vacuum Chamber . . . Purebred Steel!

You are looking at the birth of a thoroughbred . . . *cleaner, tougher, more ductile steel* . . . product of purity of line . . . with rugged strength inbred.

Here is steel designed for the most demanding jobs in the diverse industries of the world . . . steel from raw materials carefully balanced metallurgically for the electric furnace charge.

Here is quality control in its finest form *before* the birth of the ingot. At the precisely predetermined second the melt leaves the electric furnace to be transferred to the vacuum chamber where the ingot is cast . . . an ingot which, when forged to specifications, heat treated and machined, may be the rotor at the heart of a high speed power turbine.

Cleaner, Tougher, More Ductile Steel for the special demands of industry is born here.

ERIE FORGE & STEEL CORPORATION
ERIE, PENNSYLVANIA

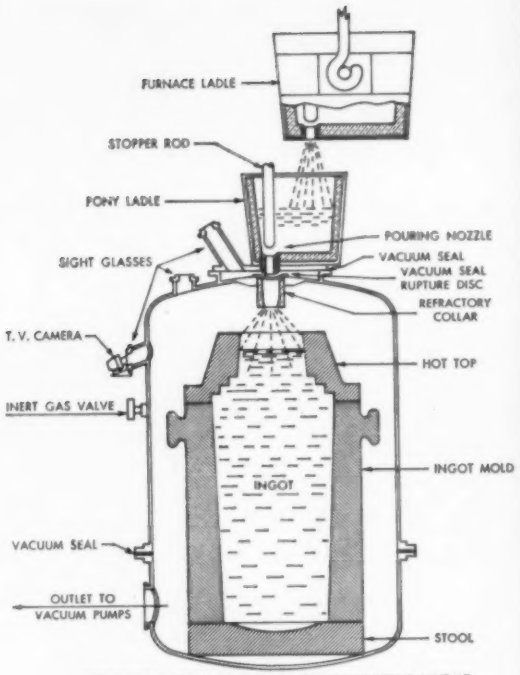
MEMBER AMERICAN IRON AND STEEL INSTITUTE

Higher Quality Steel is Born In The Vacuum Chamber . . .

Teaming the 75 ton electric furnace with vacuum casting produces the cleaner, tougher, more ductile steels which result from greater degrees of purity in the melt and in the pouring process. The jet of molten steel, discharging from the bottom of the pony ladle, melts a hole in the aluminum cover of the vacuum chamber, streaming continuously into the vacuum chamber. The absence of air in the vacuum chamber eliminates harmful gases. The result is a very minimum of hydrogen, nitrogen, oxygen and numerous volatile metals usually present. Two Television Cameras watch the operation inside the tank. One control panel, completely equipped with instruments and gauges, plus Television Screens, monitors the entire operation.

The high quality of Electric Furnace Vacuum Cast Steel meets today's demanding tests, such as ultrasonic procedures, to assure components of maximum dependability. This is but another step in the continuing program at Erie Forge & Steel to meet the needs of today's and tomorrow's industry for stronger, tougher, more ductile steels.

Complete details on Electric Furnace Vacuum Cast Steels are yours for the asking. Your problems in meeting your specific components demands will be welcomed by our technicians. Consult with us.



SCHEMATIC DIAGRAM OF VACUUM STEAM DEGASSING UNIT AT ERIE FORGE AND STEEL CORP.

Here's What We Produce:

STEEL FORGINGS FOR:

Crankshafts – Connecting rods for Diesel Locomotives – Presses – Compressors – Stationary Engines – Shafting for Naval and Maritime Vessels – Rotors for Naval and Maritime Vessels – Power Plants – Ordnance, Presses & Steam Hammers.

INGOTS

Basic and Acid Openhearth, Carbon, Alloy and Electric Steel for suppliers who do not have steelmaking facilities.

STEEL CASTINGS FOR:

Steam Hammers – Ship Castings – all types of large Presses – Rolling Mills – Hydro-Electric Engines – Steam Turbines – Crushers – Kiln Castings for Aluminum – Nickel – Tin – Magnesium and Cement Mills.

Your Nearest Erie Forge & Steel Sales Office is Listed Below

Pittsburgh 19, Pennsylvania
Sam B. Heppenstall, Jr.
475 Union Trust Building
J. R. Seiber
475 Union Trust Building
G. C. McGowan
475 Union Trust Building

New York 17, New York
William J. Vonah
60 East 42nd Street
Suite 2339

Lancaster, New York
Miller and Collins
35 Central Avenue

Milwaukee 5, Wisconsin
Dan P. Lorenz
2629 West North Avenue

Philadelphia District
Wiley B. Ford
7 E. Wynnewood Road
Wynnewood, Pennsylvania

Houston 3, Texas
E. E. Graham & Company
3701 Navigation Boulevard

Chicago, Illinois
Eugene F. Galvin
20 North Wacker Drive
Suite 1732

New Orleans, Louisiana
Morris J. Rabe, Jr., and Sons
1052 Annunciation Street

Detroit 4, Michigan
Fred T. Westmoreland
8730 West Chicago Boulevard
Suite "F"

Hudson 10, Ohio
A. G. Kessler
P. O. Box 472
190 Aurora Street

Clayton, Missouri
Claude L. Harrell
Room 307 Slavin Building

ERIE FORGE & STEEL CORPORATION

ERIE, PENNSYLVANIA

MEMBER AMERICAN IRON AND STEEL INSTITUTE

SPRING STRESSES that formerly required premium-priced materials can now be handled by Duraflex,® which costs no more than regular phosphor bronze. Write for literature and samples, today.

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PROFESSIONAL ENGINEERS, MEMBERS
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Complete engineering and manufacturing service including design and development of special machinery, mechanical products and spring actuated mechanisms. Stress analysis, spring design, metallurgical data, heat treatment, plant layout, engineering reports, selection of materials and equipment. Tools and products.

August 1, 1958

The American Brass Company
414 Meadow Street
Waterbury, Connecticut

Gentlemen,

SUMMARY OF ENGINEERING LABORATORY REPORT No. 8158

SUBJECT: Fatigue Life and Endurance Limit testing of; "DURAFLEX" Superfine-Grain Phosphor Bronze and Commercial Quality Phosphor Bronze, 5% (A) spring quality strip material.

SPRINGS: Flat spring strip was made into the usual type of contact springs used in switches, relays and instruments. These springs were deflected at about 1 cycle per second in a specially built fatigue testing machine and the deflections recorded.

STRESSES: The springs were deflected from the initial free position of zero stress to a final position having a bending stress of 77,000 p.s.i.

This stress, for phosphor bronze strip is unusually high and is higher than stresses ordinarily recommended for Beryllium-Copper or Stainless Steel for such severe service.

RESULTS: Commercial Quality Phosphor Bronze, 5% (A) springs acquired a permanent set quite early and broke at an average number of deflections of 453,374.

"DURAFLEX" springs were still satisfactory, showed no permanent set, no loss of load and no breakage at 4,000,000 deflections.

CONCLUSION: Design stresses for "DURAFLEX" can be at least 50% higher than the stresses for Commercial Quality Phosphor Bronze, 5% (A) as shown in the TOOL ENGINEERS HANDBOOK.

Respectfully submitted,

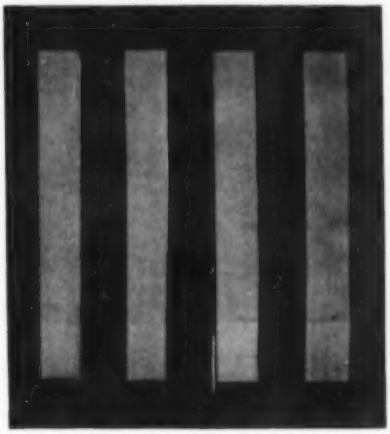
THE CARLSON COMPANY

Harold Carlson

Harold C. H. Carlson, P.E.
Licensed Professional Engineer

HC:R

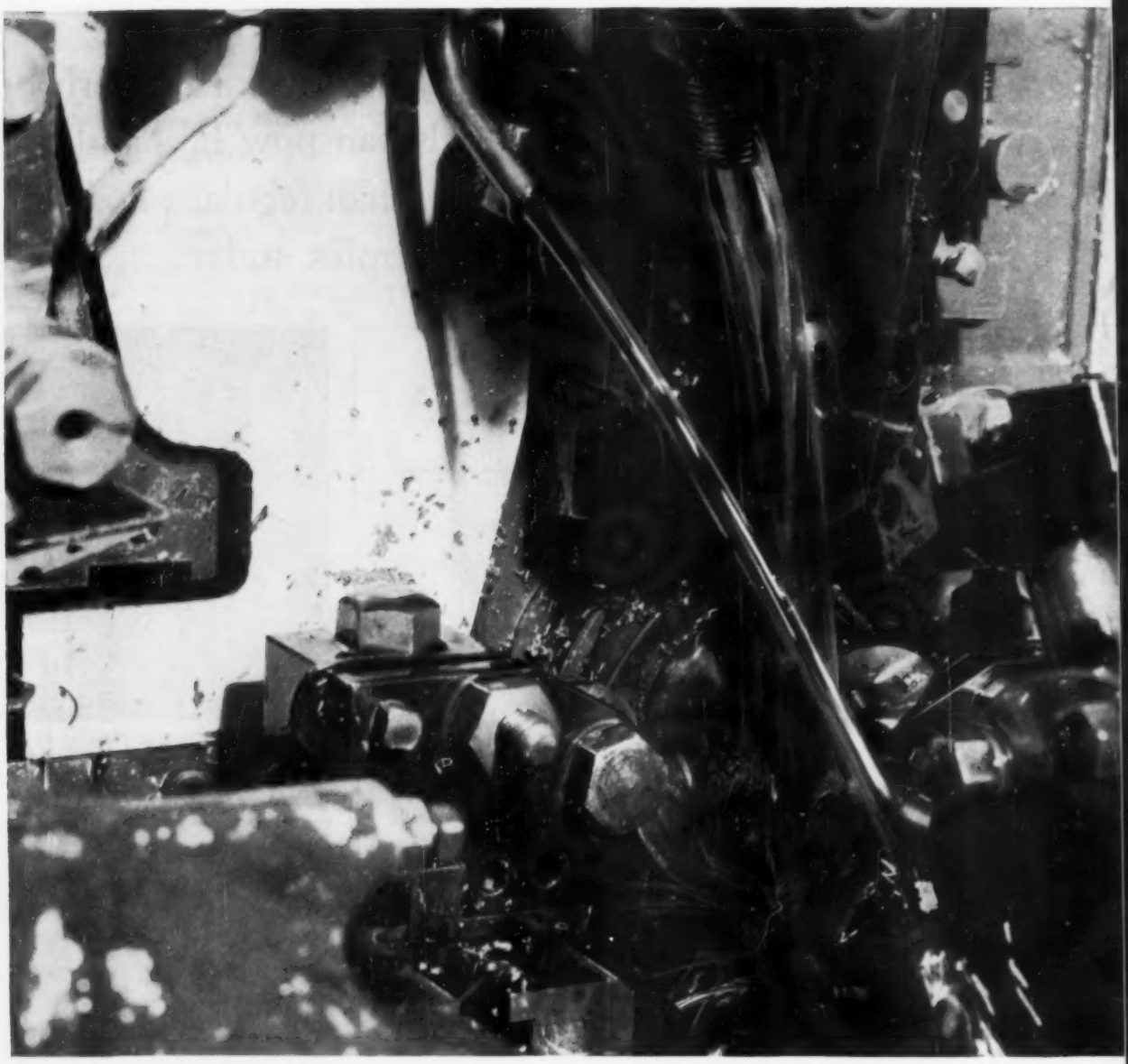
THREE SPRINGS of regular Phosphor Bronze, 5% (A), actual size, took a permanent set at about 200,000 deflections and fractured at an average of 453,374 deflections.



FOUR SPRINGS of Duraflex Superfine-Grain Phosphor Bronze, 5% (A) were still satisfactory after 4,000,000 deflections.

DURAFLEX, available in Phosphor Bronzes (A), (C) and (D), in strip and wire, offers a host of opportunities to cut costs while maintaining or improving quality and performance. For further information and technical help to select the alloy to meet your needs—call in your American Brass Company representative, or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

DURAFLEX
SUPERFINE-GRAIN PHOSPHOR BRONZE
A product of
ANACONDA®
Made by The American Brass Company



Holds tolerances of .0005 on stainless steel . . . cuts time

GULF MAKES THINGS

"Quite often we are required to hold to tolerances of .0005 on stainless steel in both automatic and hand screw machines," reports Wallace J. Perzanoski, Foreman of the Screw Machine Department, Cramer Controls Corporation, Centerbrook, Connecticut.

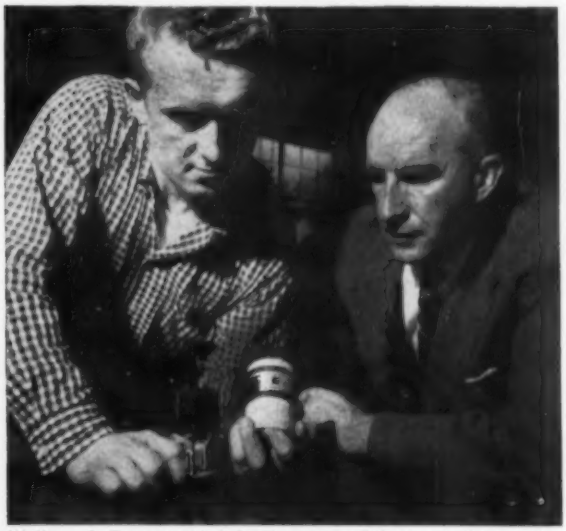
"The two cutting oils we now use . . . Gulfcut 41C for stainless steel and bronze, and Gulfcut 31A for regular brass and cold rolled steel . . . help us hold to critical tolerances. Moreover, we have shortened the time cycle on some jobs by 25 per cent," he added.

Cramer makes synchronous timing motors and precision electrical timers for commercial, industrial and military uses. Cramer's line of internal timers, time delay relays and others must meet the most critical specifications for structural and operating accuracy.

A typical precision job at Cramer is the machining of pinion posts for hermetically sealed timers which must meet rigid military specifications. Machining—on a Brown & Sharpe automatic—includes feed, rough turn, finish turn, form, cutoff and slotting.

Several years ago, Mr. Perzanoski's department was using 7 or 8 different cutting oils. After consultation

Precision machined pinion posts made by Cramer for Type 430H hermetically sealed timers. Piece is of 303 stainless steel, ½ inch long. Machining time 25 seconds per piece. Gulfcut 41C helps speed up this operation.



Wallace J. Perzanoski, left, Foreman of Cramer's Screw Machine Department, checks a timer part with B. F. Kimball, Gulf Sales Engineer. Gulfcut Cutting Oils help Mr. Perzanoski get finer finishes, closer tolerances, at higher speeds.

cycle 25% using Gulfcut . . .

RUN BETTER!

with a Gulf Sales Engineer, they reduced this to two Gulfcut oils, 41C and 31A. These two versatile oils serve for their complete range of tough machining jobs.

"Another feature of these Gulfcut Cutting Oils that our operators appreciate is the non-staining characteristic which makes them easier and cleaner to work with," said Mr. Perzanoski.

How about *your* cutting oil performance? See how Gulf makes things run better in your operation. Just call the Gulf Sales Engineer at your nearest Gulf office, or mail the coupon.

GULF

GULF OIL CORPORATION
Dept. DM, Gulf Bldg., Pittsburgh 30, Pa.

Send me more information on:

☐ Gulfcut "Regular" Cutting Oils
☐ Gulfcut Heavy Duty Soluble Oils

Name _____

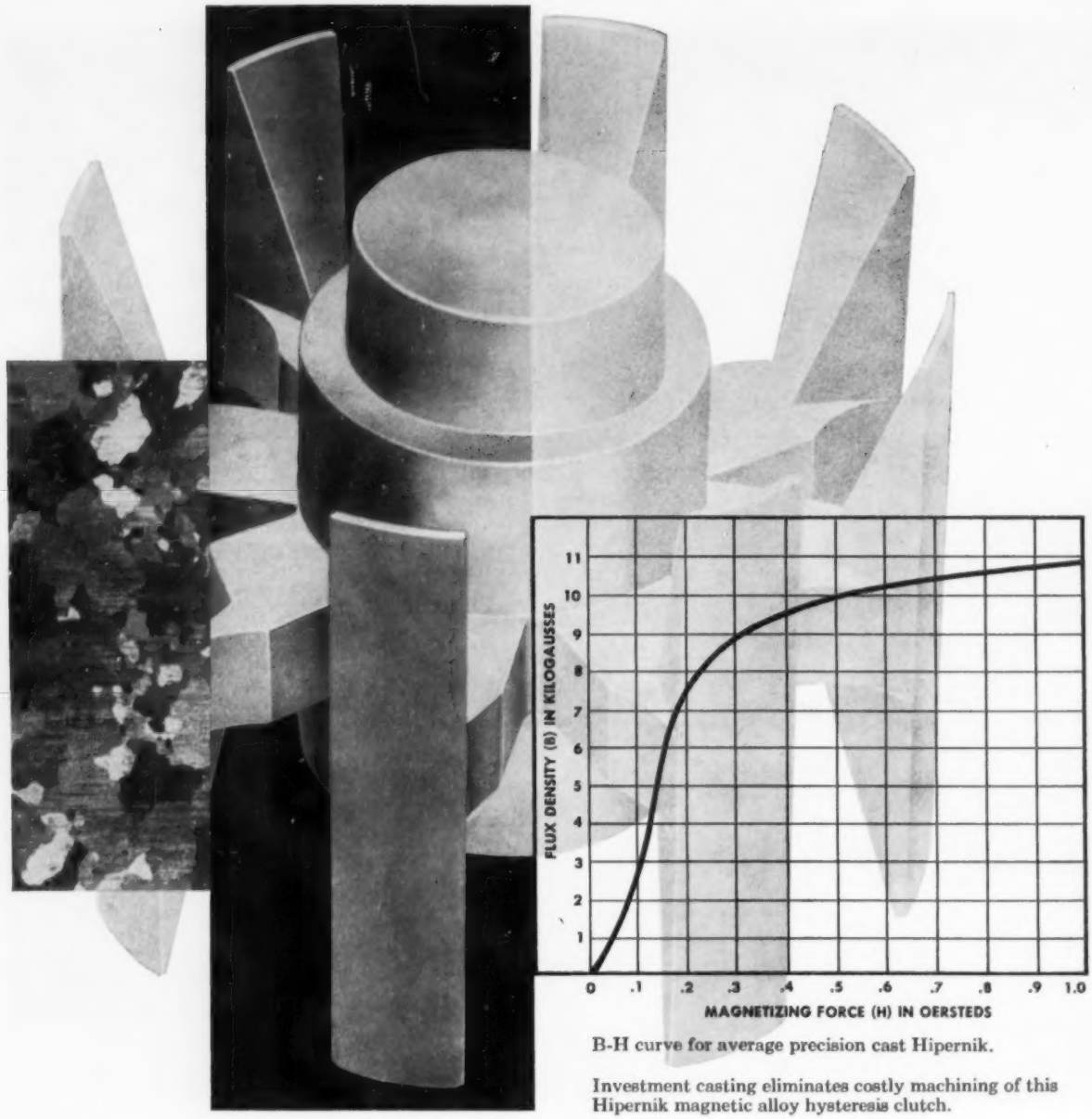
Title _____

Company _____

Address _____

City _____ Zone _____ State _____

MP-0104



B-H curve for average precision cast Hipernik.

Investment casting eliminates costly machining of this Hipernik magnetic alloy hysteresis clutch.

Westinghouse Hipernik Casting

. . . cuts costs, retains magnetic properties

The field of electronics has created special metal problems. The Westinghouse Metals Plant has accepted and solved some of these problems.

Cast Hipernik® is particularly adaptable to the requirements of missile control systems. Other applications in the electronic control and instrumentation fields are transformer cores, pole pieces, solenoids, torque motors, magnetic clutches and many special magnetic applications.

The Westinghouse Metals Plant may be able to cut your costs by eliminating unnecessary machining, yet delivering to you a completely finished component ready for assembly. This modern metals plant can furnish strip, sheet and bar stock in other magnetic and high temperature alloys. Write to: Westinghouse Metals Plant, Blairsville, Pennsylvania. Our latest bulletin on Hipernik will be sent to you by return mail. J-05005

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Metalmasters

produce every bar of Latrobe High Speed Steel!

for over 13 years . . .
fully-uniform DESEGATIZED® High Speed Steels

A fully-uniform high speed steel for every application . . .

- Electrite Double Six M-2
- Electrite Crusader
- Electrite Corsair
- Electrite No. 1
- Electrite Tatmo
- Electrite Tatmo V
- Electrite TNW
- Electrite Dynavan

Available in regular or XL® analysis for improved machinability

It takes a team of metallurgical brains and production brawn to produce the fine, fully-uniform internal structures so typical in every bar of Latrobe's DESEGATIZED® High Speed Steel.

Here are *dependable* high speed steels, more so because of the step-by-step vigilance Latrobe maintains over every production phase—from the selection of raw materials to the warehousing of the final bar or billet form. Dependable, too, because you can rely on consistent, advantageous characteristics as you work and process these steels into the cutting tools and other end products you are proud to stand behind.

Need the best high speed steel? Call on those who, by deed, are Metalmasters in this particular field—Call Latrobe!

LATROBE STEEL COMPANY

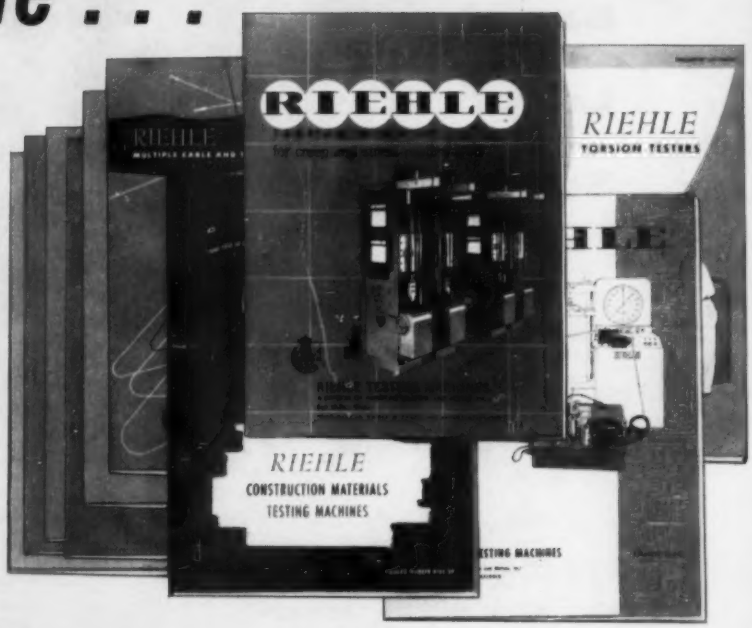
MAIN OFFICE and PLANT: **LATROBE, PENNSYLVANIA**

Branch Offices and Warehouses in Principal Cities

UPDATE

your Riehle Testing Machine reference file . . .

To help you expand your testing machine reference file, several additional* bulletins recently have been included in the Riehle collection of technical information. Simply check the list below, clip it to your letterhead, and we'll promptly send the literature you request. There is no obligation.



Check your wants

- ☐ *The Charpy Impact Machine and Procedure for Inspecting and Testing Charpy V-Notch Impact Specimens
- ☐ Universal Hydraulic Testing Machines and Accessories
- ☐ Universal Screw Power Testing Machines and Accessories
- ☐ Construction Materials Testing Machines and Accessories
- ☐ Torsion Testing Machines
- ☐ *Glossary of Terms Representing Mechanical Properties and Tests
- ☐ Creep and Stress-Rupture Testing Machines
- ☐ Losenhausen Fatigue Testing Machines
- ☐ *Newly Introduced Fatigue Testing Machines
- ☐ Riehle Electro-Balanced Indicator Unit
- ☐ Brinell Hardness Testers
- ☐ Vickers Hardness Testers
- ☐ Portable Hardness Testers
- ☐ *Hardness Conversion Chart for Hardened Steels
- ☐ Cable and Wire Testers
- ☐ Horizontal Tensile Testing Machines
- ☐ *An Axial Loading Creep Machine
- ☐ Impact Testing Machines
- ☐ Testing Machines Guide
- ☐ Riehle Recorder and Accessories
- ☐ Handsome wall plaque, reading: "One Test is Worth a Thousand Expert Opinions." ™

Riehle® TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

APPLICATION and EQUIPMENT new products

Ultrasonic Cleaning

A new line of ultrasonic cleaning tank transducers has been announced by Branson Ultrasonic Corp. Integral heater, dual thermostatic control and twin-wall construction are new features. The series comes in eight standard sizes, ranging from 1 to 32 gal. in capacity, and in transducer input

from 65 to 100 r.f. watts. Heating elements are attached to the walls of the tank. The ceramic transducers are mounted against the bottom to provide a uniform cleaning field throughout the tank. One thermostat maintains liquid temperatures at desired level; another acts as a cut-out to disconnect the heater when the tank is empty.

For further information circle No. 657 on literature request card, page 48-D.

Stainless Steel

Armco Steel Corp. has announced a new type of corrosion and heat-resistant stainless steel, Armco 22-4-9. It is available as forging billets and rounds from ⅝ to 3 in. in diameter. The alloy, which is suitable for use in the 900 to 1600° F. range, has the following composition: 0.45 to 0.60% C, 7 to 10% Mn, 0.045% P max., 0.12% S max., 1.00% Si max., 20 to 23% Cr, 3 to 5% Ni, 0.30 to 0.50% N and remainder Fe. At room temperature 22-4-9 has a hardness between Brinell 300 and 550 depending on the method of processing. Material with an initial room temperature hardness of Brinell 344 had a hot hardness of Brinell 250 at 1100° F. after 1000 hr. at that temperature.

For further information circle No. 658 on literature request card, page 48-D.

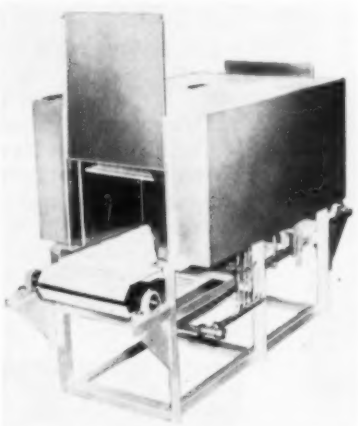
Buffing Compound Remover

A new liquid detergent which removes buffing compounds has been announced by Enthone, Inc. The new product penetrates and dissolves hardened buffing compounds by forming soluble soaps with them. Two to four gallons of Enthol 230 dissolved in water will make 100 gal. of cleaning solution. The solution is used at 150 to 200° F. Enthol 230 solutions can be used for ultrasonic cleaning.

For further information circle No. 659 on literature request card, page 48-D.

Infrared Furnace

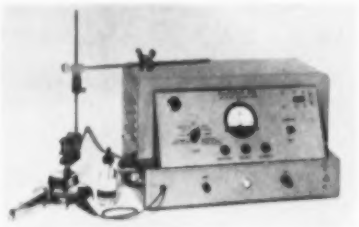
Infrared furnaces which will heat up to 2000° F. in 2 min. have been announced by Arc Engineering Corp. They can be used for soft and silver soldering, aluminum and copper brazing, bright annealing and heat treating of high speed steel. The furnaces are available in batch, conveyor or pusher-type units, widths running from 5½ to 50½ in., lengths and heights as required, with or without protective atmosphere.



For further information circle No. 660 on literature request card, page 48-D.

Plating Thickness Tester

Kocour Co. has announced an electronic tester which determines the thickness of decorative and heavy chromium, silver, tin, cadmium, zinc, copper, brass, nickel, lead, lead-tin, and tin-zinc alloy on various base metals and materials. Composite coatings of chromium over nickel over copper over steel or zinc base die-cast alloy can be tested with individual readings for each metal. A calibration feature checks the accuracy of the instrument at any time and a calibration adjustment will automatically correct high or low results on subsequent tests.



For further information circle No. 661 on literature request card, page 48-D.

Thermocouple Protection

Immersion thermocouple protection tubes which are transparent from end to end have been announced by Charles Engelhard, Inc. Their clearness facilitates emplacement of the platinum tips of the heat-measuring devices prior to their insertion into the molten metal. Made of clear quartz, the tubes have outside diameters of 7½ to 8 mm. and lengths as specified by the steel producer ordering them. They are impervious to temperatures above 2500° F.

For further information circle No. 662 on literature request card, page 48-D.

Electron Beam Welder

A new electron beam welder which joins beryllium, molybdenum, tantalum, zirconium, hafnium and other reactive and high-melting-point metals has been announced by Air Reduction Co. The electron beam bombards the materials to be welded in a high-vacuum chamber. The use of a high

Cutting back the Thermal Thicket

Solving high-temperature problems through research is part of Haynes Stellite's complete metallurgical services. This metallograph is used to observe metals at 2200 deg. F.

The great strength and high scaling resistance of HAYNES alloys at temperatures of 2000+ deg. F. are providing long service life in the hottest areas of jet engines. Flame holders, flame steps and afterburners are some of the hot spots where the properties of HAYNES high-temperature alloys are helping combat burnout, erosion, and stress in the jet, ramjet, missile, and rocket fields.

There are twelve HAYNES high-temperature alloys to choose from, formulated to handle virtually any heat condition. Among them: HASTELLOY alloy X with remarkable resistance to oxidation up to 2200 deg. F. HAYNES alloy No. 25 that resists stresses, oxidation, and carburization up to 2000 deg. F. And HASTELLOY alloy R-235, outstanding in the 1500 to 1750 deg. F. range. All are readily available.

HAYNES
ALLOYS

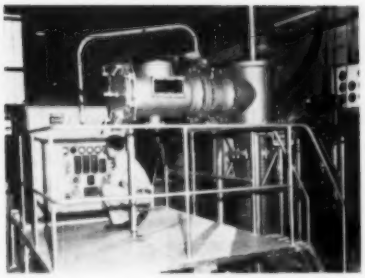
HAYNES STELLITE COMPANY

Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 420 Lexington Avenue, New York 17, N. Y.

"Haynes," "Hastelloy," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

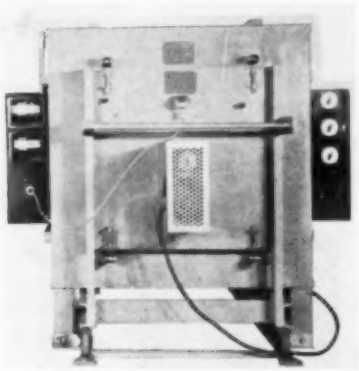


vacuum makes it impossible for the metals to be contaminated by the atmosphere during the welding process. An electron beam as small as 1/16-in. in diameter can be obtained.

For further information circle No. 663 on literature request card, page 48-D.

Oven

Grieve-Hendry Co. has announced a controlled-atmosphere retort oven for annealing brass or other metallic parts. It is electrically heated. Working space of the retort is 24 by 24 by 18 in. and the maximum continuous



working temperature is 1100° F. Two retorts are furnished with the oven, allowing controlled cooling of one batch of parts while another batch is being annealed. The retorts slide into the radiant furnace on channel tracks and are locked within.

For further information circle No. 664 on literature request card, page 48-D.

Bolts

Structural fasteners for use at temperatures up to 1600° F. have been announced by Standard Pressed Steel Co. Offered in both airframe and engine bolt configurations, the fasteners are being fabricated from M-252, Waspaloy, Udimet 500 and Hastelloy R-235. The bolts are rated at a minimum tensile strength of 155,000 psi. at 1200° F. and 85,000 psi. at 1600° F. Rated minimum stress rupture life is 100 hr. at 1500° F. and 10 hr. at 1600° F. Initially, bolts will be made in sizes from No. 6 to 1½ in.

For further information circle No. 665 on literature request card, page 48-D.

X-Ray Spectrograph

A new portable X-ray spectrograph for process control of metals and alloys, identification and sorting of metals and gaging film and plating thickness has been announced by the Instruments Div., Philips Electronics, Inc. When the standard lithium fluoride crystal is used, the instrument covers the atomic scale from No. 22 (titanium) to No. 50 (tin) in the K series and from No. 57 (lanthanum) to No. 92 (uranium) in the L series. Equipment consists of two units: a gaging or detector head containing X-ray source, detector and ratemeter, and weighing approximately 18 lb.; and power supply, electronic chassis requiring approximately 200 watts of energy from a 115 or 230 volt, 50 or 60 cycle, a.c. source.

For further information circle No. 666 on literature request card, page 48-D.

Testing Machine

Tinius Olsen Testing Machine Co. has announced a new automatic universal testing machine for production testing. The standard 400,000 lb. capacity model has a second range of 200,000 lb. Range can be changed during the test. In operation, the specimen is held by air-operated grips. Load is applied hydraulically at any speed from 0 to 6 in. per min. When the specimen fractures the machine

unloads at a speed of 20 in. per min. Maximum load is shown on an illuminated dial.

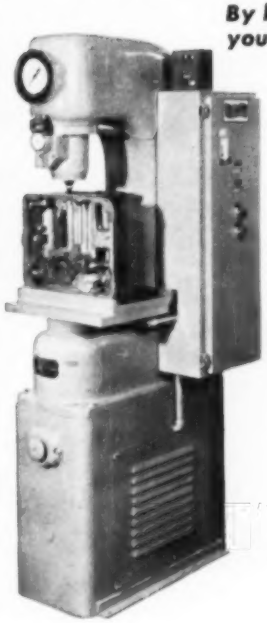
For further information circle No. 667 on literature request card, page 48-D.

Chromate Finish

The Heatbath Corp. has announced a new chromate powder, Duracoat H-6-2, for producing iridescent golden chromate finishes on zinc and cadmium plate and on zinc die castings. Duracoat H-6-2 solution is made up using 2 to 4% of the powder per gallon of water and requires no separate addi-

hardness tests increase plant capacity

By knowing the hardness of incoming parts you can reduce number of processing steps



Every production program has a bottleneck. Steel City Brinell testers can stop the broken-tool bottlenecks caused by too-hard parts.

For example, a maker of transmission cases has solved two problems with one "Color-Glance" tester. All incoming cases are tested; only hard ones need be annealed. Tool breakage is minimized, and limited annealing capacity is not overloaded.

Steel City "Color-Glance" Brinell hardness testers are high-production units. Relative hardness is shown by colored lights to reduce errors and fatigue. Optional equipment: workpiece locators, conveyor sections, counters, etc.

Steel City has solved many hardness-testing problems—laboratory, low-volume, portable. A standard machine may meet your needs.

Tell us your testing problem; ask for literature.

Steel City Testing Machines Inc.

8811 Lyndon Ave., Detroit 38, Mich.

Riverside continuous casting saves you production time, cuts rejects

Brass and other copper-based strip, rod, and wire from Riverside produces consistently better end products for you—free of weak points that result in rejected pieces or whole batches.

How do we do it? By *continuous casting*, a process we introduced to this country—a process that eliminates air holes and impurities, leaving a dense, homogeneous casting for better wire-drawing and other fabrication requirements.

Get the full cost-saving story from *Riverside-Alloy Metal Division, H.K. Porter Company, Inc., Riverside, N.J.*

good riddance to "Swiss Cheese" castings!

RIVERSIDE-ALLOY METAL DIVISION

PORTER

H.K. PORTER COMPANY, INC.

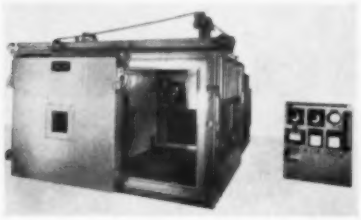
DIVISIONS: Connors Steel, Delta-Star Electric, Disston, Forge & Fittings, Leschen Wire Rope, Mouldings, National Electric, Refractories, Riverside-Alloy Metal, Thermoid, Vulcan-Kidd Steel, H. K. Porter Company (Canada) Ltd.

tions of other liquid acids for make-up or during use. The films produced are corrosion resistant and serve as bases for paint.

For further information circle No. 668 on literature request card, page 48-D.

Test Chamber

A new walk-in test chamber has been announced by American Research Corp. The chamber is 10 ft. high by 8 ft. wide by 12 ft. deep. It has a door weighing over 3 tons which is suspended from a trolley and rail and is opened or closed by a push button.

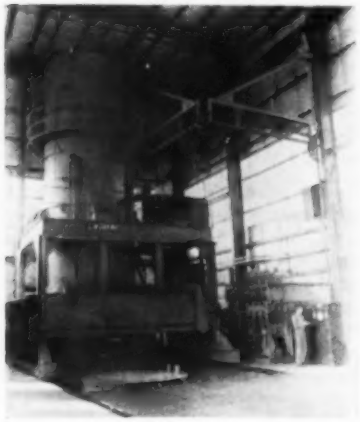


The door may be opened by push-button controls located inside the chamber if necessary. The chamber has an altitude range from ambient to 100,000 ft., temperature from —100 to +300° F., and relative humidity from 20 to 95%.

For further information circle No. 669 on literature request card, page 48-D.

Hardening Furnace

A controlled-atmosphere hardening furnace with bottom loading and discharging, spanning a pit containing an atmosphere quench chamber, a



salt quench tank, rinse tank, and draw furnace has been announced by the Lindberg Engineering Co. The furnace shell, 11 ft. in diameter by 35 ft. deep, will accommodate a loading fixture with a work load 24 ft. long by 6 ft. 8 in. in diameter. Heating elements employed for temperatures to 2050° F. are of 80% nickel, 20% chromium analysis and are mounted on the refractory in tiers so as to provide 500 kw. in five zones of control. The furnace is mounted on four wheels on 18-ft. centers with rails which allow the furnace to travel along the 57-ft. length of the furnace pit. The furnace temperature is recorded by two 24-point strip chart recorders; one for 0 to 1200° F. and the other for 1000 to 2200° F.

For further information circle No. 670 on literature request card, page 48-D.

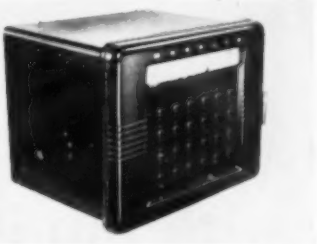
Burners

Selas Corp. has announced an improved and enlarged line of multiport P-R gas-air burners. They can be used for high-temperature alloy brazing, heat treating and silver soldering. The burner's multiport refractory screen is die-formed of ceramic materials under high pressure. The screen breaks up the flame front into a large number of small flames.

For further information circle No. 671 on literature request card, page 48-D.

Indicator

A new multiswitch indicator for checking temperatures at as many as 108 points has been announced by the Wheelco Instruments Div. Additional

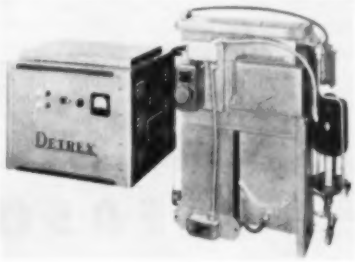


stations may be added with an additional switch housing cabinet. The basic instrument is a self-contained, null-balance unit and requires only the external sensing devices. The indicator uses an 11-in. scale, either single or dual range. Balance speeds are 2, 4 or 15 sec.

For further information circle No. 672 on literature request card, page 48-D.

Ultrasonic Cleaning

Detrex Chemical Industries, Inc., has announced a new ultrasonic unit that combines a cleaning, distillation and filtration system. It precleans,



WORD FROM Waukee...

SMALL FLO-METERS AVAILABLE: 0 TO 4 C.F.H.

If you require Flo-Meters in the ranges of 0-4 CFH and upwards for enriching or other purposes, you will want a copy of Bulletin 101 describing Waukee Type "S" meters. The bulletin includes capacity tables for the commonly used industrial gases including propane, butane, natural, endothermic, etc. These meters have 3" scale length—and are available with built-in precision flow control valve which will control flows to fractions of cubic feet per hour.

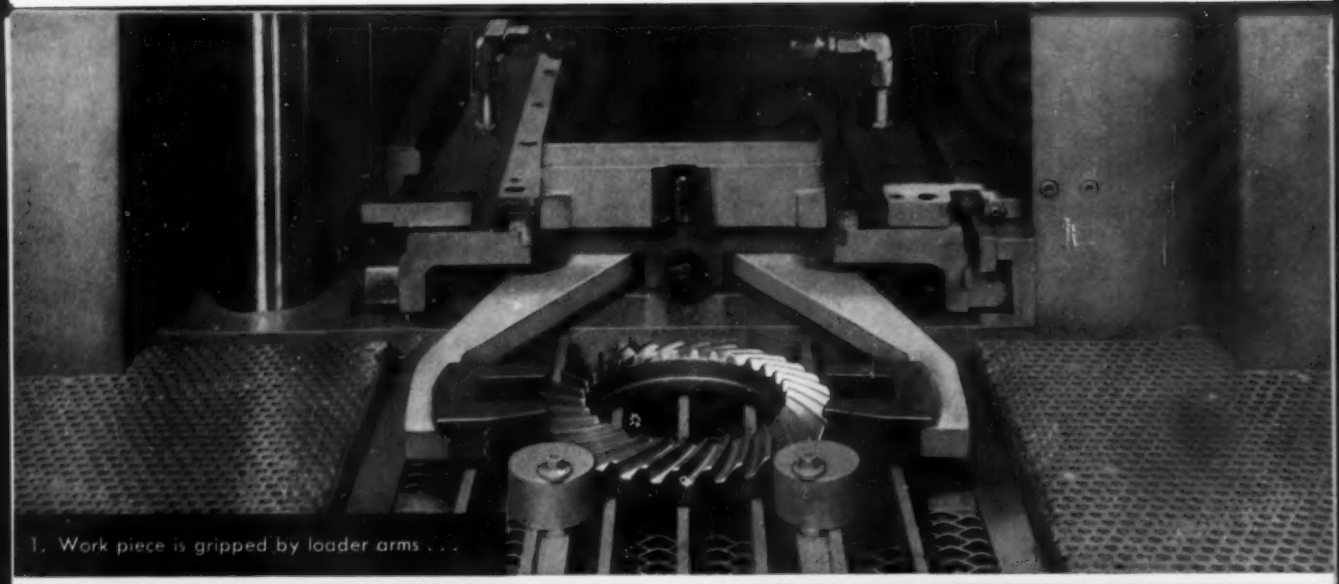
AND BIG ONES TOO! TO 25,000 CFH.

The Waukee man who covers your area will, by now, have provided many of you with information on the new, larger sizes of Waukee Flo-Meters which handle flows to 25,000 CFH. These meters are in ranges of 0-12,000, 0-15,000, 0-17,500, 0-20,000, 0-25,000 CFH. They feature the same engineering advantages which have made Waukee Flo-Meters the favorite of leading engineers and designers. All meters can be panel mounted; all are available with built-in flow control valves; all can be cleaned in a few minutes without the use of tools. Your operating people in particular appreciate the **built-in** ease of maintenance of Waukee equipment because it saves time and money and enables the equipment to be easily kept at its original accuracy.

We will be delighted to send you information on either the small or large meters, or both, if you will address Waukee Engineering Company, 5140 North 35th Street, Milwaukee 9, Wis.

R. C. O.

Waukee FLO-METERS
GAS-AIR MIXORS
ROTARY-VANE COMPRESSORS
INDUSTRIAL WASHING MACHINES



1. Work piece is gripped by loader arms . . .

2. . . . which move piece to quenching die . . .

3. . . . where controlled flexing relieves strains before quenching.

New Gleason machine quenches gears *3 times faster* with minimum distortion

The unique, fully automatic method incorporated into the new Gleason No. 117 Quenching Machine makes it possible to quench gears and other parts faster than ever before without significant distortion.

The machine discharges a piece every 30 seconds; accommodates 17 pieces in process at one time.

Automatic handling. Once a part is deposited at the front of the machine, the No. 117 positions it on a quenching die and then clamps, flexes, and quenches it. Initial quenching takes only about ten seconds.

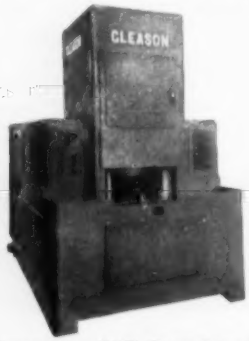
When the part cools past the critical hardening temperature, it is released from the dies. Still immersed in oil, the part then cools completely as it travels on a conveyor to the unload chute. As soon as part is released from dies, the machine is ready to receive another work piece.

Flexing before quenching. Each hot part is flexed between the dies to relieve internal stresses. Rate and number of flexes are easily preset. Hydraulic pressure produces positive diaphragming action.

Pulsing. All pressure on the work is pulsed momentarily throughout the die-quench. This permits work to contract without strain. During the die-quench, oil flows uniformly over and around the part.

Faster production. You can speed up production materially with the Gleason No. 117 Quenching Machine. It handles ring gears and cylindrical parts up to 10½″ in diameter and 8″ high. You can connect it with any conventional furnace so that parts are automatically fed to the quenching press. Push-button controls and timers are adjustable and easy to set. Dies can be changed quickly and easily.

Gleason engineers are ready to help you step up productivity with this new machine. For complete details, write for bulletin.



Gleason No. 117 Quenching Machine

GLEASON WORKS

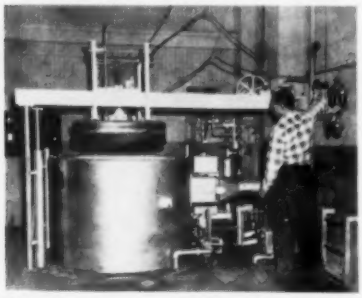
1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

ultrasonic cleans and pressure-spray rinses. The cleaner is 38½ in. wide, 17½ in. deep and 28¼ in. high.

For further information circle No. 673 on literature request card, page 48-D.

Furnace

Surface Combustion Corp. has announced a pit-type heat treating furnace in use in the production area where other operations are performed.



The furnace can handle three 550-lb. coils at a time, each measuring 26 in. in diameter. It has a temperature range of 400 to 1800° F.

For further information circle No. 674 on literature request card, page 48-D.

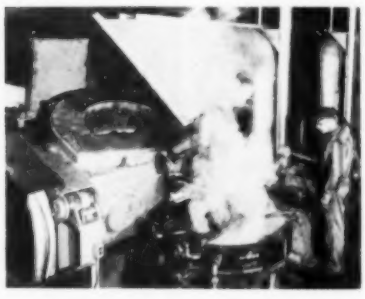
Thermocouple Conductors

A new polyvinyl insulated multiconductor cable for 6 to 56 pairs of thermocouple conductors has been announced by Thermo Electric Co. Because its outer jacket resists moisture, abrasion, heat and chemical action, Thermo-Cable can be installed in conduit, without conduit, in open troughs or in raceways. The smooth polyvinyl jacket often eliminates the special coatings required to pull extension wires through conduit. Each conductor is color-coded according to I.S.A. recommendations.

For further information circle No. 675 on literature request card, page 48-D.

Continuous Casting

A new continuous casting technique for heavy nonferrous metals and alloys has been announced by Lobeck Casting Processes, Inc. Employing semicontinuous, hydraulically operated equipment, the new method is used in the production of extrusion billets, wire bars and rolling mill slabs. Liquid metal flows from the induction furnace spout along a launder to a distributor which insures a splash-free entry of metal into the molds. The metal is cooled rapidly in passing through the water-jacketed bottomless molds and is solid by the time it leaves them. The molds are continuously filled with molten metal to match the withdrawal of the solidified castings until the ingots have been cast to their desired length. The casting machines are already being used to produce multiple-strand extrusion billets up to 10 in. in diameter and rolling-mill slabs up to 6 by 24 in., in lengths up to 20 ft.



For further information circle No. 676 on literature request card, page 48-D.

X-Ray Processor

A new automatic X-ray processing system was exhibited by Eastman Kodak Co. at the Western Metal Congress, March 16 to 20. The industrial X-Omat processor delivers an industrial radiograph in 13 min. It will process multiple narrow strips of film simultaneously and will accept film up to 17 in. wide.

For further information circle No. 677 on literature request card, page 48-D.

Pickling Baths

Amchem Products, Inc., has announced a Serseal chemical blanket for use on acid pickling baths. Advantages claimed are reduction in heating requirements up to 70%, little or no fuming, less corrosion of surrounding equipment and building, and elimination or reduction of maintenance of venting equipment.

For further information circle No. 678 on literature request card, page 48-D.

Immersion Heaters

New thermostatically-controlled immersion heaters for heating water and oil solutions in humidifiers, quench

WIDEST APPLICATION

Whatever your cleaning job may be, there is a size and type of Malleabrasive shot or grit of a specialized hardness to do your job best.

Whether you use centrifugal or air-blast cleaning equipment—whether you want shot finish or grit finish—whether you clean steel, gray iron, malleable, bronze or aluminum, whether for cleaning before surface coating, enameling, metallizing, galvanizing, you can have in Malleabrasive the right type to do it best.

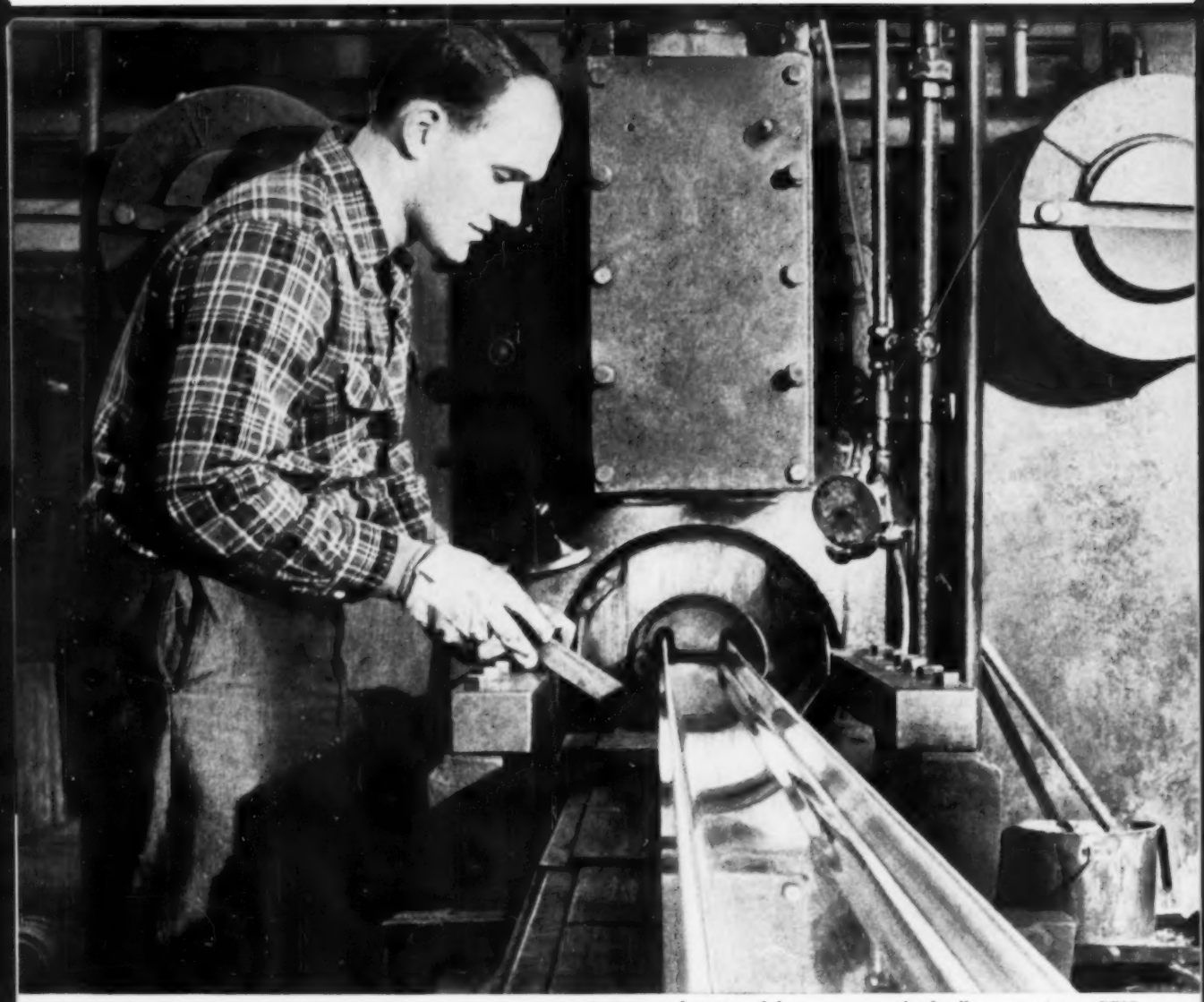
The full and complete Malleabrasive process—used by us exclusively—enables us to combine the toughness of malleable iron with various degrees of hardness to produce abrasive "tailored" to your special needs.

Our service personnel is available to consult with you without obligation. Write us.

THE GLOBE STEEL ABRASIVE CO.
Mansfield, Ohio

Sold by Pangborn Corp., Hagerstown, Md., and by many leading distributors of foundry supplies from coast to coast.

MALLEABRASIVE



An improved version of the magnesium silicide alloys, new ALCAN B51S is substantially more economical to extrude than AA-6061.

From Aluminium research...

A new kind of extrusion alloy

New ALCAN B51S aluminum alloy... extrudes more economically than its alloy equivalents... offers important new market opportunities for your extruded products.

Newest of Aluminium Limited's research developments, ALCAN B51S offers many advantages to aluminum extruders now working with AA-6061 (ALCAN 65S).

The immediate advantages of this new alloy are realized in the shop—in economy of extrusion and in the quality of the as-extruded finish. For ALCAN B51S extrudes substantially faster than AA-6061 (ALCAN 65S) with less pick-up and fewer die lines. Both advantages are particularly evident in porthole extrusions.

To the independent fabricator, the new alloy also offers increased market opportunities. Its greater strength will be valuable in many areas of aluminum application: including railings, decking, lighting standards and brackets; electrical substations and structural members of road vehicles—each and every one a new mass-tonnage opportunity for the aluminum fabricator.

For technical information on new ALCAN B51S, or for specific assistance on any ingot problem, call or write the nearest office of Aluminium Limited Sales, Inc.

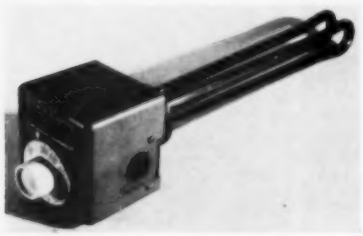
Aluminium Limited

Ingot Specialist...serving American Aluminum Fabricators—

In the U.S. — Aluminium Limited Sales, Inc.
630 Fifth Avenue, New York 20, N.Y.
Cleveland • Chicago • Los Angeles • Detroit • Atlanta

Additional distribution (Alcan Foundry Alloys):
Apex Smelting Co., Chicago, Cleveland, Los Angeles
Charles Batchelder Company, Inc., Botsford, Conn.

tanks, fuel-oil preheaters and other applications have been announced by General Electric's Industrial Heating Dept. The water heaters have a copper-sheathed heating element brazed into a brass plug and a built-in thermostat with a temperature range of 80 to 220° F. The oil heaters have a



steel-sheathed heating element brazed into a steel plug with a thermostat temperature range of 150 to 550° F. Two-inch headers are used on all units. Watts density for the water heaters is 55 watts per square inch of sheath surface. Density for the oil heaters is 20 watts per square inch. Over-all lengths of the heating units range from 15¼ to 45¾ in.

For further information circle No. 679 on literature request card, page 48-D.

Cadmium Coating

A new method for vacuum deposition of cadmium that provides protection against corrosion for high-tensile steels without danger of hydrogen embrittlement has been announced by NRC Equipment Corp. Samples, some of which had been flexed repeatedly, have passed 96-hr. salt-spray and salt-bath tests. Equipment used is a modified version of a standard metallizer and coatings up to 0.001 in. or more can be made.

For further information circle No. 680 on literature request card, page 48-D.

Inspection

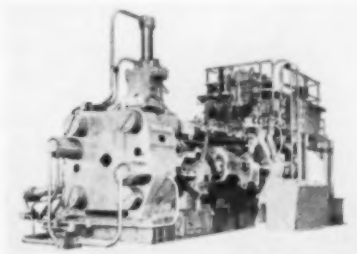
A new portable magnetic inspection device which detects surface and subsurface discontinuities in ferrous magnetic materials has been announced by Ferro Machine & Tool Corp. The unit consists of an electromagnet, a black-light hood, black light, transformer, pump for agitation,

tank, demagnetizer and auto-transformer. It operates on 110-volt, 60-cycle, single-phase current and has a d.c. magnetizing output of 5200 amp. from an input of 1.2 amp. The Detectascope may be used with fluorescent on nonfluorescent solution.

For further information circle No. 681 on literature request card, page 48-D.

Extrusion Press

Sutton Engineering Co. has announced a new 1500 to 1800-ton extrusion press for high-speed production of aluminum shapes. The new design features a two-piece main cylinder and housing arrangement, precision controls, and double-die slide to facil-

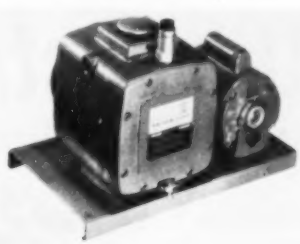


itate rapid die change. Power is furnished by two oilgear-type DY pumps driven by a 350-hp. double-ended motor.

For further information circle No. 682 on literature request card, page 48-D.

Vacuum Pump

Precision Scientific Co. has announced a new vacuum pump with a free-air capacity of 150 liters per



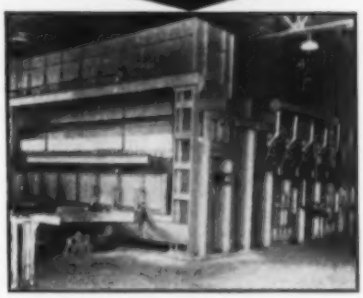
minute. Model 150 is a two-stage pump with internal vanes. It will pull down to a vacuum of 0.1 micron.

For further information circle No. 683 on literature request card, page 48-D.

Thickness Tester

General Motors Process Development Staff has announced an ultrasonic gage for measuring thickness of straight or curved surfaces of cast iron, steel, aluminum, magnesium, brass and lead when only one side of the material is accessible. This new tester has a 14-in. oscilloscope tube on which an 11-in. scale is calibrated for thickness variations to 0.001 in. When

FIRST CHOICE FOR PIPE ANNEALING



R-S CAST IRON PIPE ANNEALING FURNACES USED BY EVERY LEADING PIPE FOUNDRY

For more than 35 years leading producers of centrifugal cast iron pipe have relied on chain conveyor type annealing furnaces designed and built by R-S.

R-S experience goes back to the first centrifugal cast iron pipe produced in this country more than 35 years ago. Since then cast iron pipe annealing furnaces have been a specialty with R-S engineers. Their experience and development of furnaces to meet the needs of annealing cast iron pipe has kept pace with the industry. Today, R-S pipe annealing furnaces offer greater uniformity of heating through all ranges and precision controlled cooling.

R-S pipe annealing furnaces range in capacities from 15 to 35 tons per hour. Write for complete information on the newest developments in centrifugal cast iron pipe annealing by R-S.

R-S FURNACE COMPANY, INC.
NORTH WALES, PA.

R-S FURNACES

TOCCO Induction Heating unit and SWIFT-OHIO press mechanism work together for better, flash-free buttwelding of pipe and tubing.

Speedy Buttwelding
That Leaves No Flash

with TOCCO* Induction Heating

and Press Mechanism by SWIFT-OHIO

Now, in less than a minute you can get flash-free, smooth joints on any size pipe, regardless of its diameter or wall thickness.

Conventional buttwelding methods produce strong, sound joints but leave a brittle flash inside or outside the pipe. Inside flash can seriously impede fluid flow. Particularly on long lengths of pipe, removal of this inside flash is a real production headache—time consuming and expensive.

Whether *your* production bottleneck involves buttwelding, soldering, brazing, heat treating or forging, it pays you to investigate TOCCO as an economical way to do it better, faster and at lower cost.

THE OHIO CRANKSHAFT COMPANY

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Please send reprint of article from STEEL Magazine entitled "Buttwelder Leaves No Flash".

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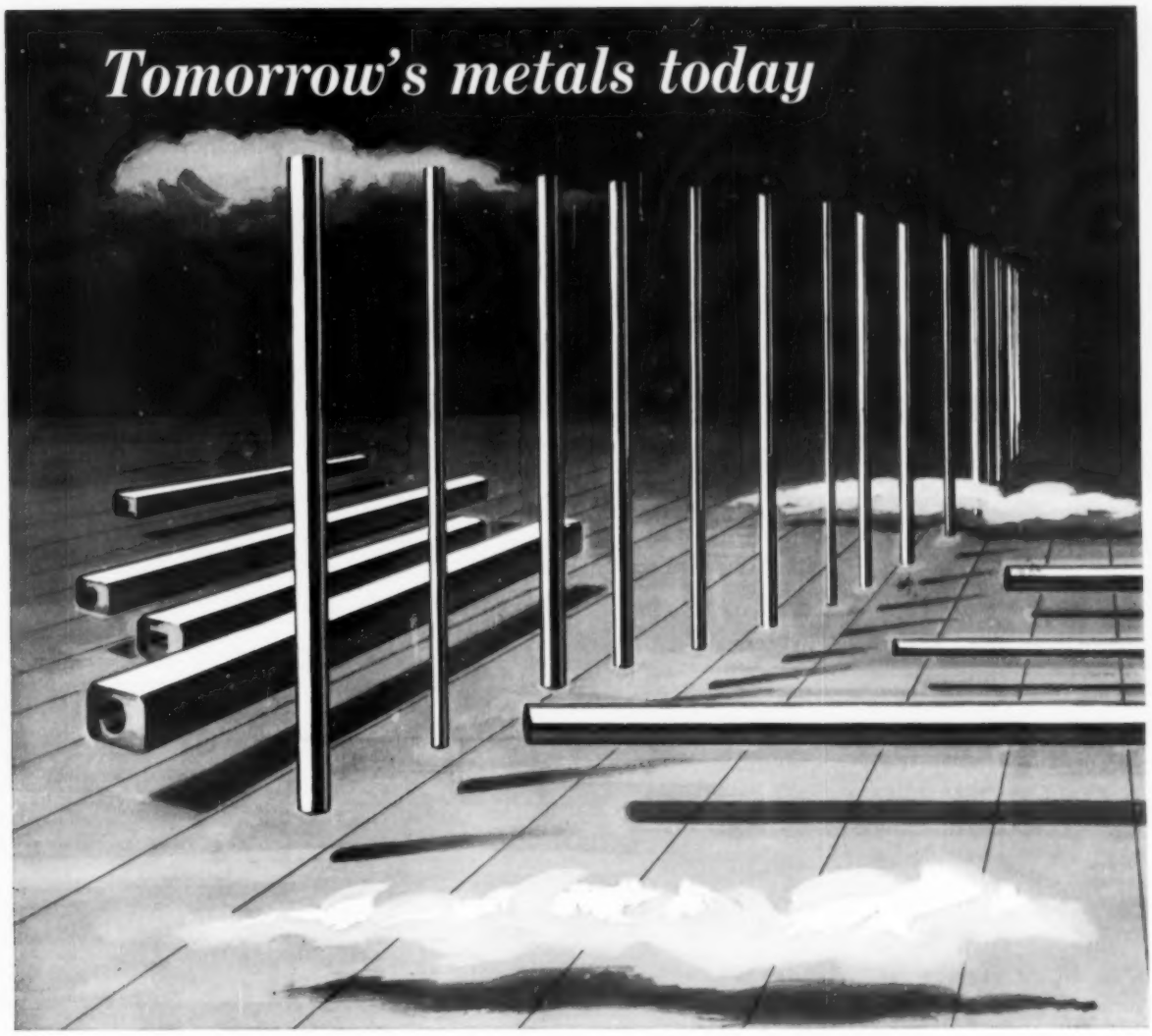
Address_____

City_____ Zone____ State_____



through custom-made ingots and electrodes
—from Sylvania

Today, the metals industry is meeting the challenge of tomorrow's metals requirements with new high-temperature alloys developed through powder metallurgy.

Sylvania, through its Chemical and Metallurgical Division, is supplying the raw materials for these metals of the future. It mixes, presses and sinters ingots and electrodes from powdered metals to meet the most exacting alloy requirements.

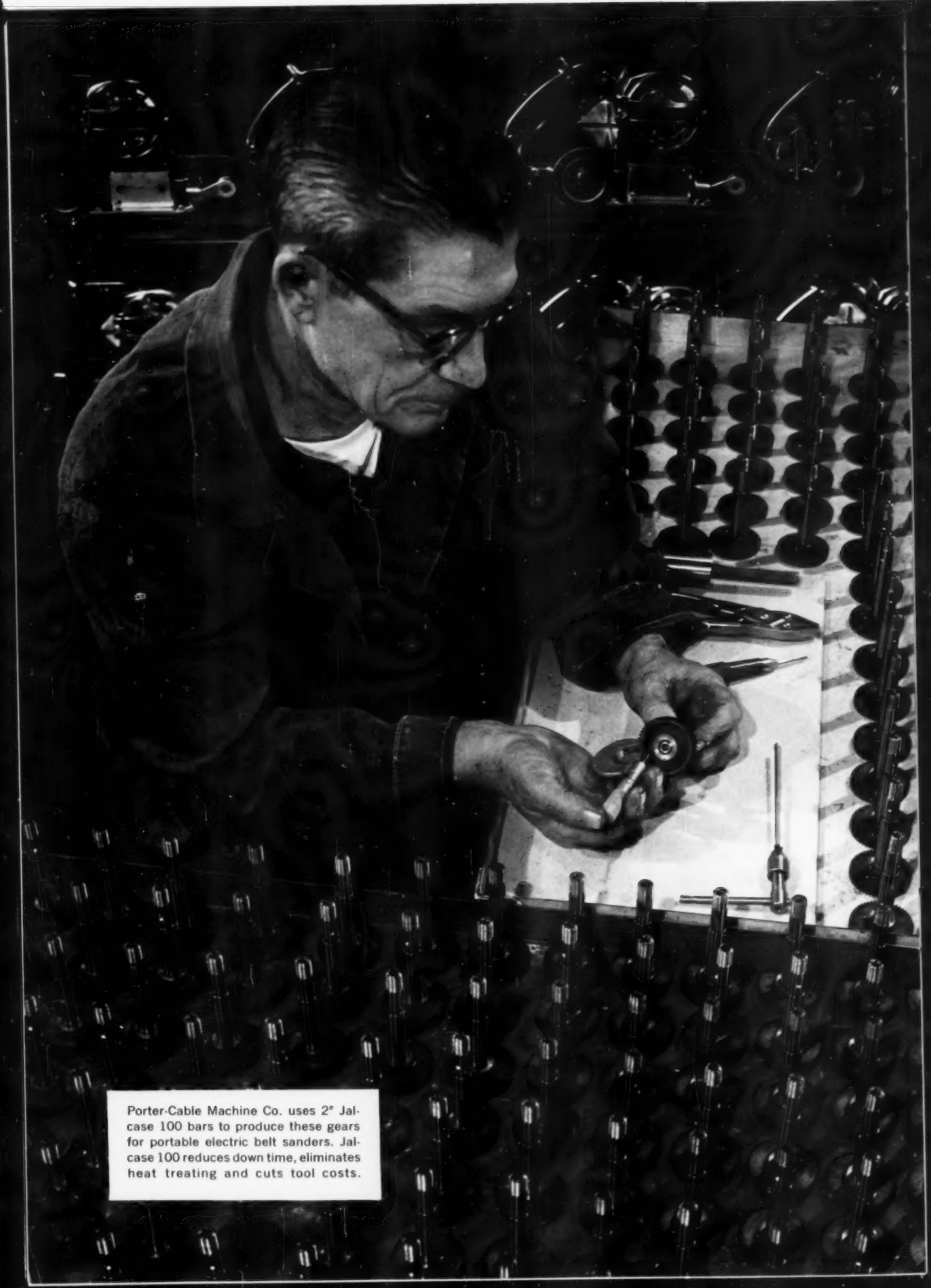
Special heat-resistant alloys and pure Copper, Nickel, Tantalum, Titanium, Chromium, Tungsten and Molybdenum are isostatically pressed and sintered in a wide range of sizes and shapes. Emphasis has been placed on evaluation sizes down to ½" diameter tailored to specific experiments. If desired, Sylvania will process your own sponges or powdered metal mixtures to your specifications.

If you're experimenting with new high-temperature metals requiring prefabricated ingots or consumable electrodes, Sylvania welcomes the opportunity to work with you—write today stating your needs.

SYLVANIA

Sylvania Electric Products Inc.
Chemical & Metallurgical Div.
Towanda, Penna.

TUNGSTEN • MOLYBDENUM • CHEMICALS • PHOSPHORS • SEMICONDUCTORS



Porter-Cable Machine Co. uses 2" Jalcase 100 bars to produce these gears for portable electric belt sanders. Jalcase 100 reduces down time, eliminates heat treating and cuts tool costs.

"Jalcase 100 increased tool life 50%, eliminated need for heat treating"

. . . reports Porter-Cable Machine Co.

"J&L's Jalcase 100 meets our requirements for a steel that satisfies these four specifications:

1. Enough hardness for use in gears and jack shafts without need for heat treating;
2. High machinability for profitable operation without down time;
3. Uniform metallurgical structure;
4. Minimum distortion from residual stresses.

"Our shop experience with Jalcase 100, on six-position automatic machines with up to 21 high speed tools, shows tool life is increased at least 50%, hob life increased 30%," states Porter-Cable Machine Company official, Syracuse, N.Y.

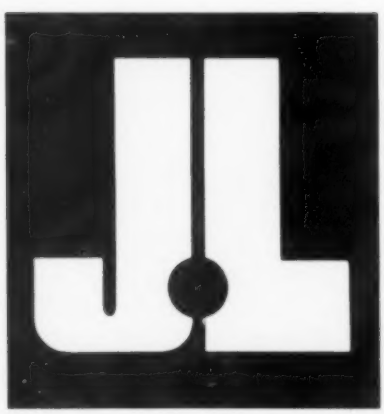
Jalcase 100 is a new grade of Jalcase cold finished steel bars, specially processed for easy machinability with minimum distortion. It features guaranteed minimum yield strengths up to 105,000 p.s.i., guaranteed minimum hardness up to 248 Brinnell, and stabilized residual stresses. A new leaded product known as Jalcase 100-L is believed to be the most machinable high strength steel yet developed.

Call in a J&L steel specialist for a recommendation on the cold finished steel bars best suited for your specific operations. Chances are he can speed your production, cut your machining costs. See your local distributor, or write to Jones & Laughlin, 3 Gateway Center, Dept. 563, Pittsburgh 30, Pennsylvania.

Jones & Laughlin Steel Corporation

PITTSBURGH, PENNSYLVANIA

Where cold rolled steels originated in 1859



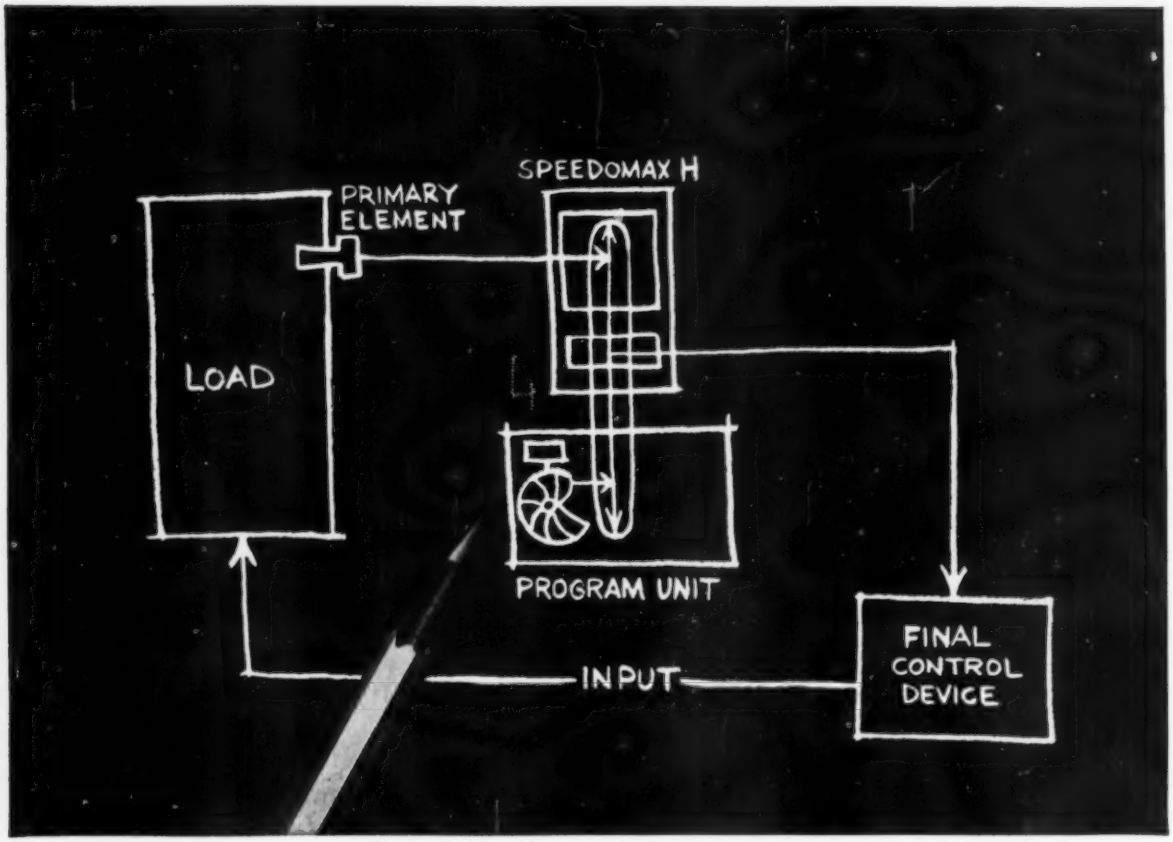
Final J&L pre-shipment spot inspection

Many bar sizes are used by Porter-Cable

Helical gear cutting hobs last longer

Increased tool life speeds production

High wear resistance is assured



Reproduce your time-temperature cycles exactly with L&N cam-type program control

At the flip of a switch you can heat . . . soak . . . and cool at a preset rate for a preset time with L&N's improved cam type program control! Whether your program is linear or non-linear, this control will continuously regulate input to reproduce *your* cycle . . . again and again.

Heart of the system is the program unit. Essentially it's a motor-operated cam and a control slidewire. The cam is calibrated . . . making it extremely easy to lay out and cut to any time-temperature cycle. Changing a cam to meet a new program takes only a minute. For additional flexibility, the unit has seven standard speeds . . . permitting a multiple number of programs.

Other elements in the control system include a primary element, a Speedomax® recorder and associated control relay, and a final control device. Any change detected by the primary element and measured by the recorder is checked by the program unit, which regulates the final control device to keep the process on cycle.

Also available is a motor-operated front setter type of program control. Recommended for linear programs only, this system offers great flexibility within the range selected.

Both types are available for Two-Position or proportioning control . . . will regulate input to electric or fuel-fired furnaces.

Can your process benefit from programmed heating and cooling? If so, it'll pay you to investigate L&N program control. For more information, call your nearest L&N office, or write 4927 Stenton Ave., Philadelphia 44, Pa. Ask for Data Sheet ND46-33(4).

LEEDS & NORTHRUP
Instruments — Automatic Controls • Furnaces

cylinder wall thickness is substandard or too thin, a red low-limit light flashes. The gaging unit is housed in a portable cabinet.

For further information circle No. 684 on literature request card, page 48-D.

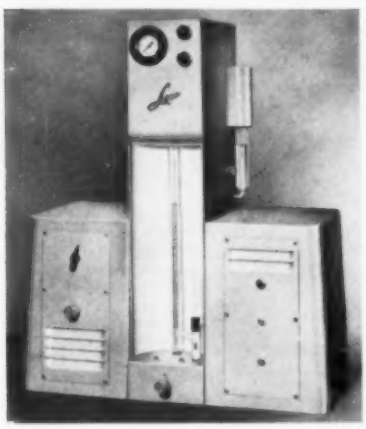
Zinc Alloy

A new zinc-base die alloy has been announced by American Smelting and Refining Co. The alloy has high impact and high tensile strength. It is workable and no special casting or machining techniques are required to fabricate it. Formaloy is used in such applications as in drop-hammer punches and dies, draw-press dies, stretch-press dies, blanking dies and hydropress forming blocks.

For further information circle No. 685 on literature request card, page 48-D.

Carbon Determinator

Laboratory Equipment Corp. has announced a new series of gasometric carbon determinators. The new line



consists of a hand-operated unit, a semiautomatic determinator and a completely automatic model. In all three units, all rubber tubing connections are completely hidden. Protective mountings reduce or eliminate glass breakage. Float valves are rubber-coated and specially mounted for easy removal and caustic pipets are enclosed for safety.

For further information circle No. 686 on literature request card, page 48-D.

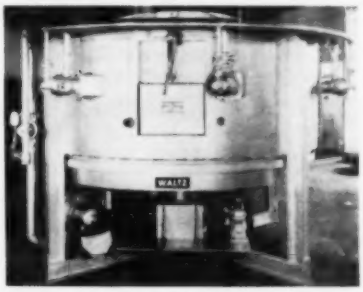
Wear Strip

Ampco Metal, Inc., has announced a new line of extruded rectangular wear strip of a special copper-base alloy. It is available in 46 sizes. The mechanical properties of this extruded alloy range from 100,000 to 108,000 psi. ultimate tensile strength, 50,000 to 55,000 psi. yield strength and 200 to 230 Brinell (3000 kg. load).

For further information circle No. 687 on literature request card, page 48-D.

Furnace

Waltz Furnace Co. has announced rotary-hearth furnaces from 3 to 10 ft. in diameter for continuous operation in either forging or heat treat-



ing. The furnace illustrated can supply temperatures from 1200 to 2300° F. The hearth is doughnut shaped with a 7 ft. 6 in. O.D. and a 30-in. column in the center. The height of the chamber is 15 in. The furnace has gas burners mounted on the lining, which fire against the direction of rotation of the table. Oil or electric burners are optional.

For further information circle No. 688 on literature request card, page 48-D.

Finish

Heatbath Corp. has announced a new powdered chromate product known as Duracoat M-2-P for producing blue-bright, stain-resistant finishes on zinc plate. One-half ounce of Duracoat M-2-P plus a small amount of nitric acid is required to make 1 gal. of solution.

For further information circle No. 689 on literature request card, page 48-D.

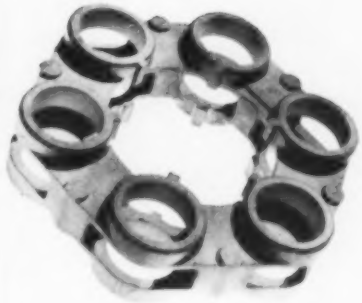
Salt Bath Control

A kit for periodic check of salt bath neutrality has been announced by A. F. Holden Co. Test readings show degree of bath breakdown from over-

heating, infiltration of sulphur or alkalies. An operator can be trained to use the kit in about 15 min.

For further information circle No. 690 on literature request card, page 48-D.

Rx



an
INVESTMENT
CASTING
of course

because investment casting means easier, more consistent, more uniform parts with higher properties at lower cost.

made of
RxMET ALLOYS
of course

because RxMET alloys give better, more consistent results through precise metallurgical control.

smart designer
smart producer

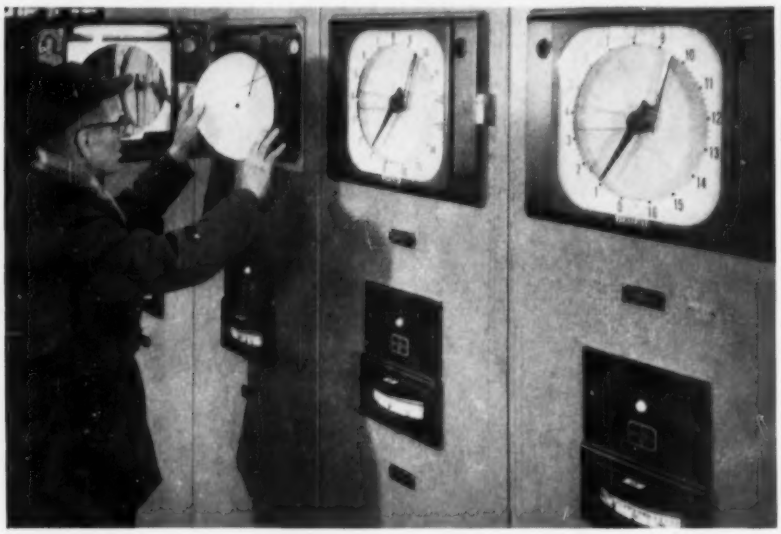
because both specify investment casting alloys by:

WAI MET
ALLOYS CO.
1999 GUOIN STREET
DETROIT 7, MICHIGAN

BRISTOL'S

Instrumentation News

• *News of instrumentation and automatic control in industrial heating and metallurgy* •



Instruments help turn out casting cores at 7 tons/hour

Engine blocks for Ford and Mercury automobiles are cast with strictest attention to accuracy and structural quality at the Cleveland foundry of the Ford Motor Company, Brookpark, Ohio, just outside Cleveland.

Yet these rigorous requirements must not impede the smooth flow of the production line. That's one reason Ford installed this battery of Bristol Dynamaster* instruments.

Another: In the early days, core baking used to be an all-night process. Cores were of fine quality, but the output was too low for present-day production lines. The new core baking method turns out top quality cores at the rate of 7 tons an hour. Bristol instruments automatically hold the baking temperature to 450° ± 5°F. And, in emergencies, allow faster processing by raising the temperatures and increasing conveyor speed.

First oxygen steel plant uses Bristol controls

Bristol round chart Dynamaster* Instruments (top) and Bristol Metagraphic miniatures (center row) play a big part in controlling oxygen steel-making at Dominion Foundries & Steel, Ltd.

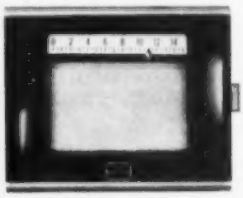
When Dominion Foundries & Steel, Ltd. (Dofasco), at Hamilton, Ontario, first introduced this method of steel-making to the North American Continent, they chose Bristol instruments and controls (above) to supervise the most critical steps in the process.

These include oxygen pressure and flow (current rate and total), lance position, lance cooling water temperature, flow, and pressure as well as various other temperatures.

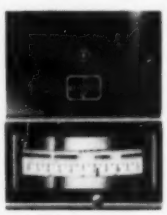
The big advantage of oxygen steel-making is the lower original investment in equipment. Only about 50% of the equipment costs of competitive processes is required and operating costs are no higher, with equal or better product.

Furnace, oven, dryer— Bristol controls them all

Whatever your industrial heating application, you can find a Bristol instrument or instrument system to provide precision indication, recording or automatic control. The following instruments, in almost innumerable variations, are typical of the truly complete Bristol instrument line.

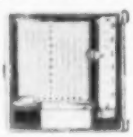


Bristol's Dynamaster* Potentiometer Pyrometers come in round or strip chart models, provide electronic recording, indication, and electric or pneumatic control, including high-low contact, proportional, time-program and many combinations. The outstanding instrument for maximum precision.



Bristol Millivoltmeter Pyrometers. Both indicating and controlling models available. Controlling models utilize unique Bristol Free-Vane* principle that completely eliminates relay "chatter" or "flutter." High-low contact and proportional models available in a wide variety of combinations.

Bristol Miniature Instruments – Bristol is the only company offering a complete line of instruments in both miniature *and* full-size for all recording, indicating and control applications, both electronic and pneumatic. True plug-in construction. Ideal where panel space must be conserved.



*T. M. REG. U. S. PAT. OFF.

Write for complete data on Bristol instruments for your furnace, oven, dryer or kiln. And remember, Bristol makes a complete line of thermocouples and pyrometric accessories. The Bristol Company, 10[illegible] Bristol Road, Waterbury 20, Conn.

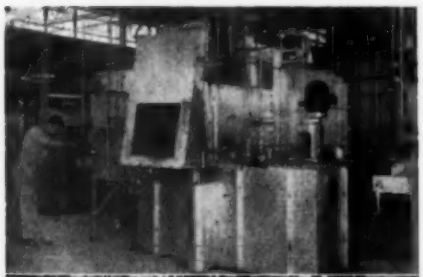
B-26

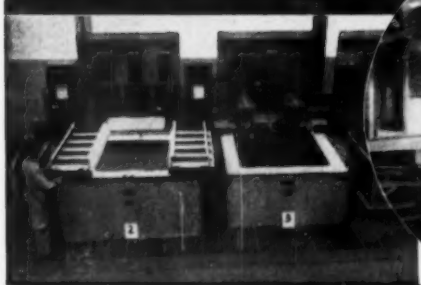
BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

WHEN IT COMES TO HEAT TREATING—
"Do-It-Yourself" can sometimes be costly

Buying equipment and supplies to perform heat treating operations within your own plant is only one step in many that must be considered when contemplating the installation or expansion of a heat treating department.



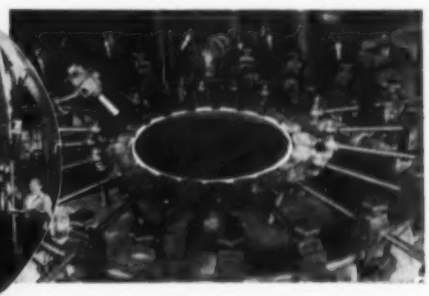


Here are some of the factors that should be included when figuring the cost of operating your own heat treating department—of "doing-it-yourself" when it comes to heat treating:

- **Technical skill:** Trained operators whose skill is the result of years of experience are essential
- **Maintenance:** Rapid deterioration of equipment occurs unless there is constant repair, maintenance, and skillful handling of the equipment
- **Quality control:** Testing equipment and skilled operators are necessary to maintain uniformity and quality control of all heat treating operations
- **Sufficient equipment and supplies:** A great variety of equipment is needed to meet the requirements of annealing, brazing, hardening, carburizing, stress relieving, nitriding, and all other heat treating processes; and an endless variety of materials and supplies must be kept on hand.

These problems and many more have been solved by commercial heat treaters. They have the answers because heat treating is their business.

Every MTI commercial heat treater listed here is a specialist with complete service facilities under one roof. Each one has the facilities, equipment, skill and experience which will enable him to meet your most exacting heat treating requirements.



Consult any of these HEAT TREATING SPECIALISTS

American Metal Treatment Co.
Elizabeth, New Jersey
Anderson Steel Treating Co.
Detroit, Michigan
Benedict-Miller, Inc.
Lyndhurst, New Jersey
Bennett Heat Treating Co., Inc.
Newark 3, New Jersey
Cook Heat Treating Co. of Texas
Houston 11, Texas
The Dayton Forging & Heat Treating Co.
Dayton 3, Ohio
Dominy Heat Treating Corp.
Dallas, Texas
Dreves Company
Bethayres, Pennsylvania
Greenman Steel Treating Company
Worcester 5, Massachusetts
Fred Heinzelman & Sons
New York 12, New York

MTI CERTIFIED METAL TREATING INSTITUTE

Alfred Heller Heat Treating Co.
New York 38, New York
Hollywood Heat Treating Co.
Los Angeles 38, California
Ipsenlab of Canada, Ltd.
Toronto, Ontario
Ipsenlab of Rockford, Inc.
Rockford, Illinois
L-R Heat Treating Co.
Newark, New Jersey
The Lakeside Steel Improvement Co.
Cleveland 14, Ohio
Metallurgical, Inc.
Minneapolis 14, Minnesota
Metallurgical, Inc.
Kansas City 8, Missouri

New England Metallurgical Corp.
South Boston 27, Massachusetts
Owego Heat Treat, Inc.
Apalachin, New York
Paulo Products Company
St. Louis 10, Missouri
Pittsburgh Commercial Heat Treating Co.
Pittsburgh 1, Pennsylvania
The Queen City Steel Treating Co.
Cincinnati 25, Ohio
J. W. Rex Company
Lansdale, Pennsylvania
Scott & Son, Inc.
Rock Island, Illinois
Stanley P. Rockwell Company
Hartford 12, Connecticut
Syracuse Heat Treating Corp.
Syracuse, New York
Temperature Processing Co., Inc.
North Arlington, New Jersey

now a

ROTATING BURNER

for CINCINNATI flamatic

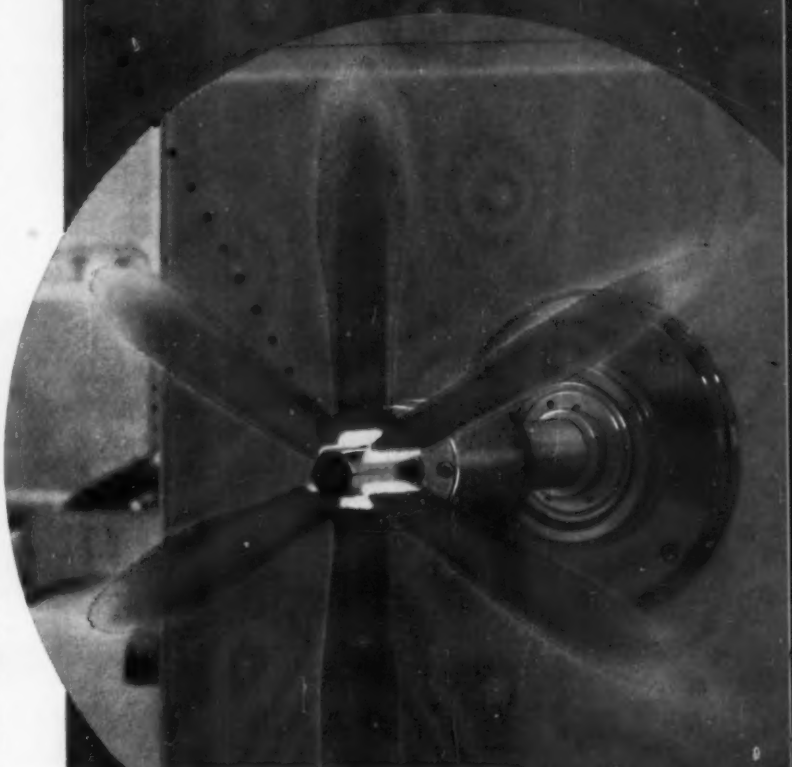
Flame Heating Machines!

- **flame head spins within the area of the part to be heated**
- **simplifies spin hardening of parts difficult to rotate—eliminates expensive fixtures**
- **cuts hardening costs all around**

This newest development of the Meta-Dynamics Division Heat Treating Laboratories brings lower costs to precision selective flame heating of a wide range of parts, because the flame head rotates—*not* the work. The gas-tight rotating joint of the burner has undergone more than 1000 hours of test, with no sign of leakage.

The rotating burner and workholding fixture mount on the flat bed of the basic machine, which contains a quench tank and part removal conveyor. Automatic timing, temperature and quenching control are provided. A separate control cabinet provides accurate control of gas, oxygen, air and water. Other "building blocks" (flame heads and fixtures) are available for such work as brazing and spot, spin, progressive and combination spin-progressive hardening.

For your heat processing work, look to the Cincinnati Flamatic for lowest cost flame heating . . . and the Cincinnati Inductron (built in 15, 30, 50 KW capacities) for lowest cost induction heating. Call in a Meta-Dynamics Division field engineer for full details.



TYPICAL PARTS SUCCESSFULLY HARDENED BY THE FLAMATIC ROTATING BURNER

INTERNAL THREAD of steering knuckle control arm, a pearlitic malleable casting, hardened to Rc 58-60. I.D. is 1⅜"; thread length, 1⅛"; overall part length, 22½".

INTERNAL TEETH of SAE 1052 Ring Gear, hardened to Rc 58-60. Gear I.D. is 5¼"; tooth face, ⅛".

inductron
flamatic
hardening machines

META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating

THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.

CINCINNATI

APPLICATION and EQUIPMENT new literature

692. Abrasive Cleaning
Catalog 57-WX on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass*

693. Abrasives
Selection chart for basic coated abrasives for metalworking operations. *Abrasives Div., Carborundum Co.*

694. Abrasives
New catalog on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods. *Cleveland Metal Abrasive*

695. Air Conditioners
6-page Bulletin 135 on air engineering for the process and chemical industries. Heat removal, heat and moisture control. *Niagara Blower Co.*

696. Air Dryers
Bulletins D-102, D-103 and D-106 on steam and electric reactivated air and gas dryers. Flow diagrams, operation. *C. M. Kemp*

697. Air-Hardening Steel
New 8-page booklet gives composition, properties, elevated-temperature properties and heat treatment. *Latrobe Steel*

698. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

699. Alloy Steels
New 46-page Booklet 415-C on alloy steels. 9 pages of tables giving chemical composition ranges, limits. Grain size, heat treatment, quenching mediums. *Bethlehem Steel Co.*

700. Aluminum Alloys
File on high-strength aluminum alloys gives advantages, applications, properties. *Frontier Bronze Corp.*

701. Aluminum Alloys
Technical Data Bulletin IND-18 on aluminum-iron alloys for applications requiring high quality soft magnetic materials. *General Plate Div., Metals & Controls Corp.*

702. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

703. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

704. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

705. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

706. Ammonia
6 and 4-page bulletins on ammonia storage units and nitrogen generator. *Hamler Industries, Inc.*

707. Ammonia
New technical bulletin on commercial and refrigeration grades of anhydrous ammonia. Physical-chemical properties, specifications. *Sun Oil Co.*

708. Atmosphere Cooling
Bulletin T-40 on automatic heat treating units with controlled atmosphere cooling. *Ipsen*

709. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

710. Austempering
Tips and Trends, Vol. 12, No. 1, discusses mechanized austempering of harrow disks. Heat treat line diagramed. *Ajax Electric*

711. Bar and Tube Machinery
New 18-page booklet on billet peeling and chipping, centerless turning, straightening and roll grinding machinery. *Foundry & Mill Machinery Div., Blaw-Knox*

712. Barrel Finishing
29-page book on such barrel finishing processes as deburring, coloring, burnishing, descaling, cleaning, rust prevention. Case histories. *Magnuson Products Corp.*

713. Belt Surfacing
12-page discussion of procedure and equipment for rough grinding of metallurgical specimens. Metal Digest, V. 2, No. 5. *Buehler, Ltd.*

714. Beryllium
24-page booklet on properties, corrosion resistance, machinability, formability and joining of beryllium. Toxicity of beryllium and beryllium as an alloying material. *Brush Beryllium Co.*

715. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal," contains uses, formulas, calculations. *W. M. Chace*

716. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

717. Blast Cleaning
8-page bulletin 1403 on liquid blast cleaning equipment. Drawings of cabinets. *Pangborn Corp.*

718. Blowers
Bulletin 300 on series of blowers to fit individual requirements. Drives used. Performance curves. *North American Mfg. Co.*

719. Boron Stainless
8-page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel*

720. Brass
Publication B-39 on superfine-grain drawing brass. Properties. Finishing characteristics. *American Brass*

721. Brazing Stainless
24-page booklet discusses characteristics of base and filler metals, brazing cycles, selecting and using gas atmospheres, construction and application of various types of furnaces. *Harper Electric Furnace*

722. Burners
Buzzer Catalog No. 1570 describes industrial gas burners, furnaces and accessories for heat treating, metal melting, soldering and drying. *Charles A. Hones*

723. Burners
4-page bulletin on multiport gas-air burners. Capacities, sizes, advantages. *Selas Corp.*

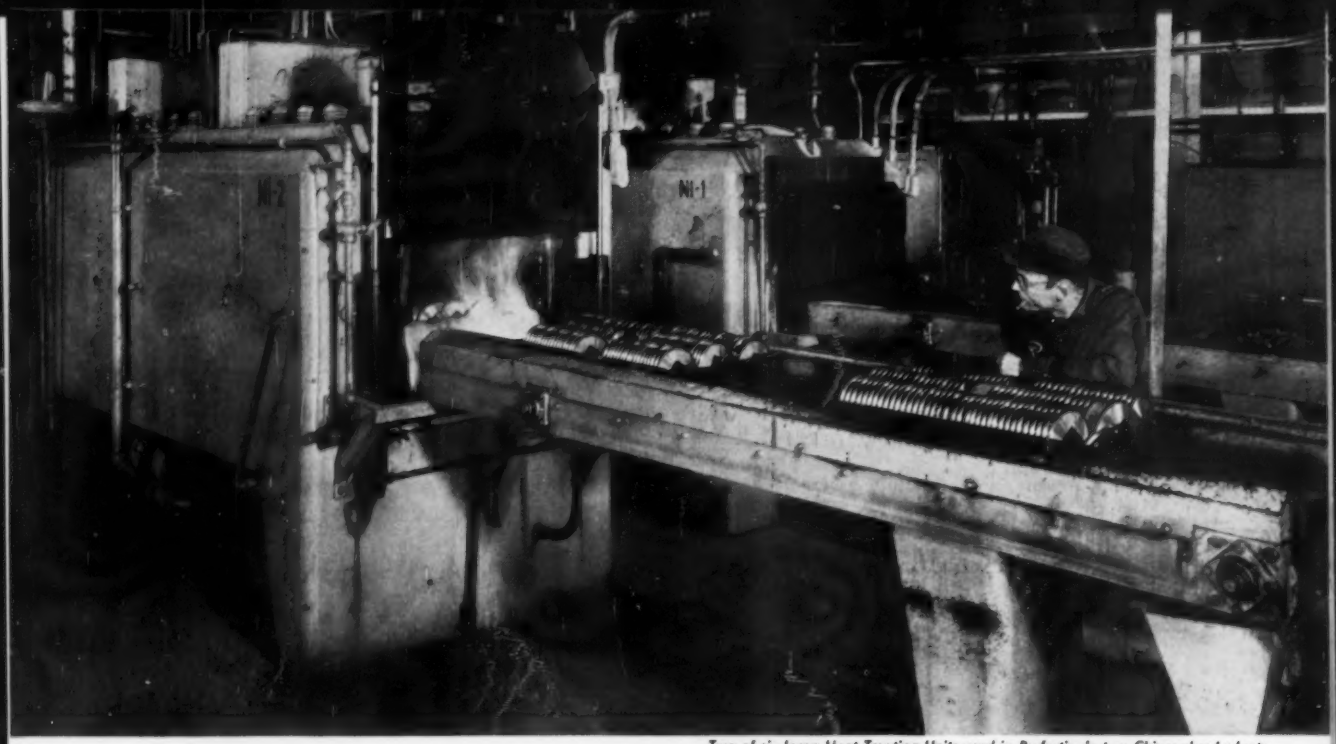
691. Cemented Carbides
New 32-page catalog describes carbide brazed tools, inserts, tool holders and blanks. Each type of tool is pictured and its dimensions and method of pricing tabulated. In a general information section, the various grades for metal cutting and for compacting, drawing, forming, blanking, coining and wear resistant applications are described. Four tungsten carbide grades are also included. Charts compare crater resistance, edge wear and shock resistance of the six metal cutting grades. The catalog charts speed-and-feed and grade recommendations for cutting cast iron, carbon and alloy steels. *Carmet Div., Allegheny Ludlum Steel Corp.*

724. Carbides
New 52-page catalog on carbide blanks, inserts, tools and tool holders. How to select and use various grades. *Coromant Dept., Sandvik Steel, Inc.*

725. Carbon Control
16-page bulletin on equipment for carbon and sulphur determination, including combustion furnaces. *Harry W. Dietert*

726. Castings
12-page bulletin on ArmaSteel castings. Properties, applications, machinability and heat treating. *Central Foundry Div.*

727. Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*



Two of six Ipsen Heat Treating Units used in Perfection's two Chicagoland plants

"...with Ipsen heat treating units, we get bright work, and increase production per man-hour."

Perfection Tool and Metal Heat Treating Co.

Don Petersen is president of Perfection Tool and Metal Heat Treating Company, one of Chicago's largest and best known custom heat treating organizations. To learn firsthand how and why Perfection uses semi-automated, controlled atmosphere, heat treating equipment, we had an interesting chat with Mr. Petersen. Here are his answers to our questions:

Q. Since 1951 you have purchased a number of Ipsen "straight-through" heat treating units. Why have you favored this equipment?

A. We were well pleased with the first Ipsen furnace we bought, and our customers were well satisfied with the quality of the work that came out of it. Since the end of World War II, there has been a much greater demand for atmosphere work, and, as this demand increased, we have purchased additional furnaces. We have four Ipsen units in our Hubbard Street plant . . . and two in our branch plant in Lombard, Illinois. All six units have two work chambers which make them ideal for preheating.

Q. What kind of work do you handle in your Ipsen equipment?

A. In the course of the average day we handle many, many different types of work . . . gears, screw machine parts, stampings, etc. We use your furnaces for carburizing, carbonitriding, neutral atmosphere hardening, and carbon restoration. The versatility of Ipsen furnaces is quite a selling point as far as we are concerned.

Q. Have you been able to increase production with this equipment?

A. Yes. With Ipsen equipment we have substantially increased production per man-hour. One reason for this is that quenching is automatic . . . and our operators do not have to handle parts in and out of the quench by hand.

Q. Apparently you like the automatic quench feature. Why?

A. Definitely. The automatic timing makes it easy to duplicate previous quenching results. We eliminate the element of human error in quenching.

Q. What about maintenance of your Ipsen equipment?

A. You have an excellent record on this count. We find that your equipment requires very little maintenance.

Q. What do your men think of Ipsen equipment?

A. Our men like your equipment because it's cleaner, cooler, and easier to operate. It takes less effort per pound of work treated.

Q. Has Ipsen equipment permitted you economy of floor space?

A. Yes. We find your equipment to be quite compact for the amount of work handled. In our Hubbard Street plant four Ipsen units are placed so the discharge ends converge on the same washing and degreasing unit. The entire installation occupies only 600 sq ft of floor space.

A brochure describing the type of Ipsen equipment used in the Perfection plants is available. Ask for your copy.

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Brochure on plaster mold castings of brass, bronze, aluminum, beryllium copper. *Ohio Precision Castings, Inc.*

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10-page Bulletin 90 on precision etching of metal parts by chemical and electrolytic means. *Superior Tube*

730. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

731. Cleaning
16-page manual on steam cleaner phosphating process. The value of phosphating, methods of application, application of steam cleaner method. *Malsbary Mfg.*

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12-page Bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

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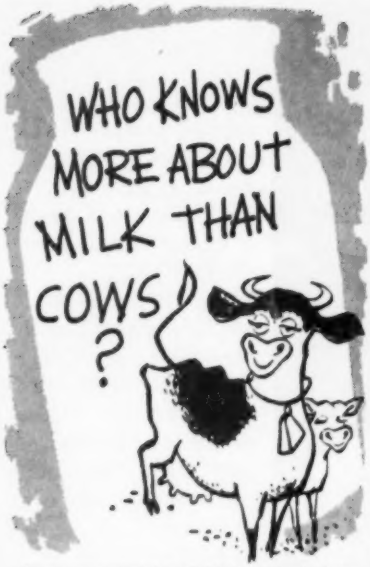

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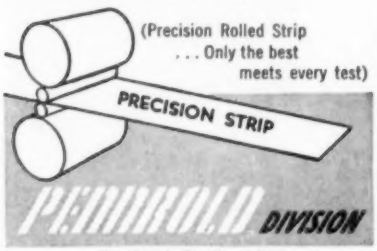

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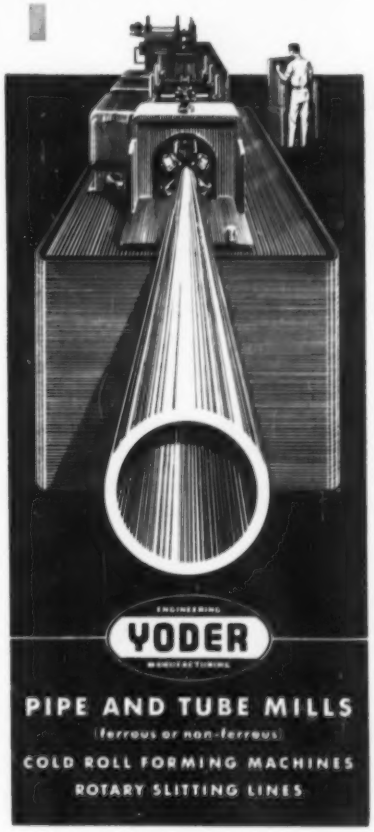

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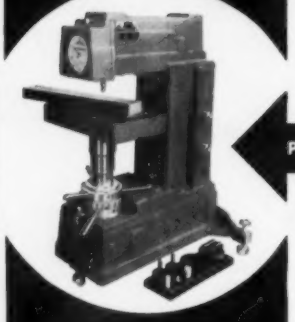

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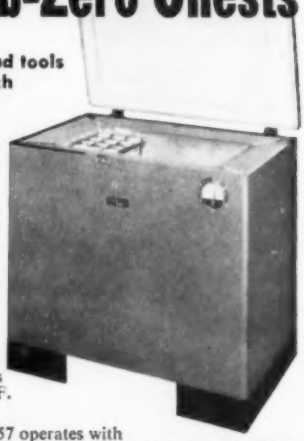

Model RSZ503 Rivet Cooler (shown) equipped with 90 rivet canisters, temperatures to –30° F. 110V, 60 cycle, single phase.

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			Rm. 70°	Rm. 110°	L	W	H	L	W	H
Sub-Zero	SZH153	1.5	–95° F.	–85° F.	42″	28″	42¾″	23″	9″	12½″
Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60″	28″	42¾″	47″	15″	16″
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60″	28″	42¾″	47″	15″	16″
Rivet Cooler	RSZ503	5.0	–30° F.	–20° F.	42″	28″	41″	30″	16″	18″

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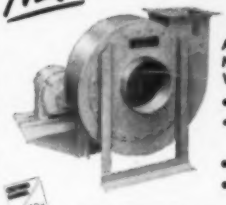

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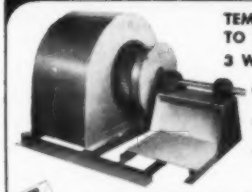

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4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

791. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

792. Hardness Testers
20-page Catalog DH-325 on normal hardness testing. Applications, advantages, accessories. *Wilson Mechanical Instrument Div.*

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Folder on shaker-hearth furnaces and push-through muffle furnaces for annealing, hardening and brazing stainless steel. *American Gas Furnace Co.*

797. Heat Treating
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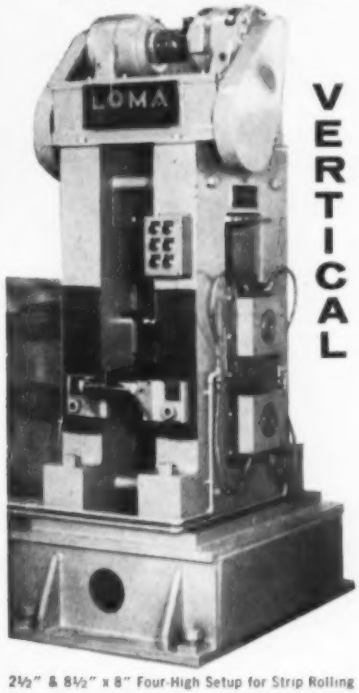

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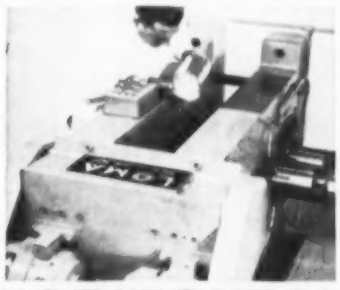

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The new LOMA Model 1000 Two-High/Four-High Combination Rolling Mill offers maximum versatility for both laboratory use and production application. With the rolls arranged in a vertical plane, the mill is employed for (a) hot or cold two-high breakdown rolling of flats and shapes; and (b) four-high cold finish rolling of sheet and strip. With the rolls arranged in a horizontal plane, the machine is used for the continuous compacting of powder metals into strip.

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803. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

804. Heat Treating Fixtures
16-page Catalog M-7 on heat treating baskets and corrosion resistant alloy fabrications. *Wiretex Mfg. Co.*

805. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

806. Heat Treatment
Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

807. Heaters
New Bulletin GEA-6306A on immersion heaters for heating oil. Product data in table form. Circulating and non-circulating oil heaters. *General Electric*

808. Heating Element
12-page catalog on 35-20 nickel-chromium-iron heating element. Temperature-resistance curve, physical property tables and factors to consider in designing furnace elements. *Hoskins Mfg.*

809. High-Strength Steel
4-page bulletin on Yoloy "E" steel. Properties, corrosion resistance and strength. *Youngstown Sheet & Tube*

810. High-Temperature Alloys
New 12-page booklet describes Nicrotung and W-545 superalloys for turbine disks and blades. Properties, structure. *Materials Mfg. Dept., Westinghouse Electric*

811. High-Tensile Steel
8-page bulletin on properties and composition of N-A-X high-tensile steel. Examples of resistance to impact, fatigue, abrasion and corrosion. *Great Lakes Steel*

812. High-Vacuum Equipment
24-page catalog on high-vacuum equipment for laboratory and industry. Pumps, valves, gages, leak detectors, metallizing equipment and furnaces described. *Consolidated Electrodynamics Corp., Rochester Div.*

813. High-Vacuum Pumps
Bulletin 990 gives specifications and pumping speed curves of two models. *F. J. Stokes*

814. Induction Heaters
12-page bulletin gives descriptions, technical data on various sizes. Water systems diagramed, and standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

815. Induction Heating
Bulletin 20-30 on high-frequency power source and control unit. Diagrams of units. *Inductotherm Corp.*

816. Induction Heating
High Frequency Review contains article on high temperature fatigue tests using induction heating. *Lepel High Frequency Laboratories*

817. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

818. Industrial Equipment
12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment, *R. C. Mahon Co.*

819. Inspection
Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux Corp.*

820. Inspection
16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument Div.*

821. Insulation
16-page Bulletin R-2-H on insulating firebrick. Properties of six grades and applications of each. Design of arches and circular linings. *Refractories Div., B. & W. Co.*

822. Laboratory Equipment
New bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

823. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

824. Lubrication
26-page manual on lubrication of miniature instrument bearings. Various types and brands of oils and greases available to bearing designers and users. *Miniature Precision Bearings*

825. Magnesium
53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

826. Marking Machines
Bulletins 146-C25 and 146-C26 on complete line of marking machines, from stationary models to portable units. For polished surfaces, precision finished parts, glass, ceramics. *Jas. H. Matthews*

827. Metal Laminates
8-page bulletin on metals used, advantages, applications, properties. *Bridgeport Brass*

828. Metal Marking
New bulletin on all-purpose electric pen which will arc etch any metal. *Newage Industries*

829. Metal Sorting
Data on nondestructive sorting tool for raw, semifinished or finished parts. *J. W. Dice*

830. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

831. Microscope
New brochure SB56 on cycloptic stereoscopic microscope. *American Optical*

832. Microscope
Technical Bulletin HHS-2 on vacuum heating stage which permits specimens to be examined at temperatures ranging from room temperature to 2000° F. Application, specifications. *Unitron Instrument*

833. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment. *Bausch & Lomb*

834. Molybdenum
24-page booklet gives physical and chemical property data on molybdenum powders, wire, alloys. *Sylvania Electric*

835. Nondestructive Inspection
8-page bulletin on use of ultrasonic Reflectoscope describes principles of ultrasonic inspection and its uses. *Sperry Products*

836. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

837. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

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(Continued from page 47)

838. Nuclear Graphite
New 8-page bulletin tabulates properties, high-temperature strength, resistance to corrosion and thermal shock, thermal conductivity and machinability. *National Carbon Co.*

839. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

840. Ovens
Bulletin 4-257 on gas, oil and electric ovens. Load carrying door, electric drawer and walk-in type ovens. *Grieve-Hendry*

841. Ovens
16-page Bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Bros.*

842. Paint Stripper
4-page folder on paint stripper which also removes plastic coatings. Directions for its use. *Oakite*

843. Perforated Metals
4-page folder gives ordering specifications and patterns. *Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp.*

844. Phosphor Bronze
New 4-page brochure on effects of precision annealing on spring-temper phosphor bronze sheet and strip. *Waterbury Rolling Mills, Inc.*

845. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

846. Polishing
12-page bulletin on grinders, polishing and buffing lathes, dust collectors. 46 models described and illustrated. *Hammond Machinery Builders*

847. Pouring Practice
New 8-page brochure gives six hints on improving metal pouring practice. *Vesuvius Crucible Co.*

848. Powder Metallurgy
Technical literature on high-density sintered metal parts. *Supermet Div., Globe Industries*

849. Powdered Iron
Properties of Plast/Iron with and without copper. *Plastic Metals Div.*

850. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

851. Presses
Data on mechanical and hydraulic powdered metal presses of 8 to 500-ton capacities. *Haller, Inc.*

852. Protective Coatings
8-page brochure on chemicals and processes for metal protection. Chemicals meeting government specifications. *Amchem Products, Inc.*

853. Pyrometer Supplies
56-page Bulletin P1238 on thermocouples and pryometer accessories. Engineering data on selection and installation. *Bristol*

854. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

855. Quenching
New bulletin on automatic quenching machine for volume production. Features, advantages, operation. *Gleason Works*

856. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

857. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

858. Radioisotopes
8-page booklet on cobalt-60, cesium-137, iridium-192 and how they are used in radiography. Gamma and X-ray radiography compared. *Ansco*

859. Refractories
24-page bulletin on physical and chemical properties of super refractories. Applications. *Refractories Div. Carborundum*

860. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3500° F. *Morganite, Inc.*

861. Refractory Metals
26-page booklet on tungsten, molybdenum, tantalum and columbium. Properties, drawing, extrusion, applications, bibliography. *Fansteel Metallurgical Corp.*

862. Rust Prevention
Nine bulletins in one folder on rust prevention. Theory of corrosion. *Rust-Lick, Inc.*

863. Salt Bath Carburizing
5-page booklet on liquid carburizing with advantages and disadvantages of the salt bath process. *American Cyanamid*

864. Sand Control
32-page book on defects and troubles in foundry and how to remedy them through sand control. *Claud S. Gordon*

865. Sealant
6-page bulletin on Loctite sealant. Applications, methods of application. *American Sealants Co.*

866. Seamless Tubing
8-page Bulletin TB-340A on seamless mechanical tubing. Combinations of types, grades, sizes, surface finishes, tolerances. *Tubular Products Div., B. & W. Co.*

867. Shell Molding
Report on lubricants for shell molding. Methods of shell sand coating. Properties of three lubricants. *Nopco Chemical*

868. Shot and Grit
14-page catalog describes cast steel, malleable iron, chilled iron, cut wire and other forms of abrasive shot and grit. Methods of shot peening and impact cleaning. *Abrasive Shot & Grit*

869. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *National Metal Abrasive*

870. Silicon Alloys
New leaflet on 13 grades of ferrosilicon and three grades of silicon metal. Applications. *Vanadium Corp.*

871. Soldering Fluxes
4-page bulletin on line of non-acid, self-cleaning fluxes. How they work. *Lake Chemical Co.*

872. Spectrograph
8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

873. Spring Steels
6-page folder gives applications, materials, finish and size range. Analyses. *Sandvik Steel*

874. Springs
8-page bulletin on spring design. Stress and deflection formulas for various types of springs. Physical properties of commonly used spring materials. *Associated Spring*

875. Stainless Castings
28-page booklet of data on stainless castings. Analyses, properties, handling and heat treatment. Typical applications. *Allegheny Ludlum Steel*

876. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

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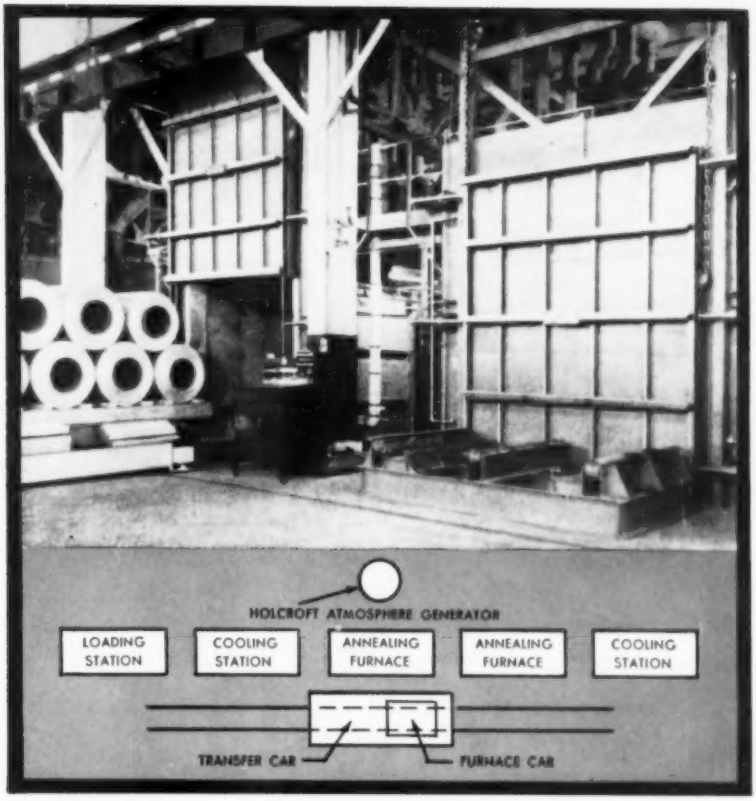

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carbon stainless steel. Chemical analyses, design, fabrication, mechanical properties. *Armco*

878. Stainless Steel

20-page catalog on corrosion resistance, applications and working characteristics of 20% chromium—29% nickel stainless steels, with and without columbium. *Carpenter Steel*

879. Stainless Steel

44-page book gives detailed information on use of stainless steel in the chemical industries. *Crucible Steel*

880. Stainless Steel

8-page catalog of stainless sheet and plates. Analyses, finishes, sizes. *Eastern Stainless Steel Corp.*

881. Stainless Steel

Pocket card gives instructions for making a chemical spot test to distinguish 200 series from 300 series stainless steels. *Electro Metallurgical Co.*

882. Stainless Steel

Two booklets on 200 series of low nickel, austenitic stainless steels, give applications and properties compared with 300 series. *Republic Steel*

883. Stainless Steel Wire

New 20-page manual on stainless steel wire. Analyses, mechanical properties, corrosion data, applications. *Jones & Laughlin*

884. Stainless Steels

28-page booklet on special purpose stainless steels. Types, finish characteristics, uses, corrosion data, cleansing agents. *Washington Steel*

885. Steel

Reference data sheet on Vasco M-2 (tungsten-molybdenum) high speed steel. Heat treatment, composition, applications. *Vanadium-Alloys Steel Co.*

886. Steel

256-page handbook lists sizes, weights, lengths, steels available, shapes. Data on mechanical properties, standard steel compositions, hardness numbers conversions. *Ryerson*

887. Steelmaking Additive

Data on additive which cleans melts without changing analysis. *WaiMet Alloys*

888. Strain Gages

New catalog of SR-4 strain gages, instruments and accessories. Electrical and physical specifications of each gage type. *Baldwin-Lima-Hamilton*

889. Surface Heating

Four-page Bulletin GEA-6146B shows how to select heating equipment and controls for surface heating. *General Electric*

890. Surface Temperature

Bulletin No. 4257 on Pyrocon, surface temperature instrument. *Illinois Testing Laboratories*

891. Temperature Measuring

Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil® Corp.*

892. Testing

Literature on pickle pills for testing strength of pickling solutions. *Ferro Corp.*

893. Testing

10-page article, Bulletin M-2, on testing copper single crystals. *Instron Engineering Corp.*

894. Testing

Brochure on facilities for metallurgical testing. Methods of analysis of high-temperature alloys. *Frank L. Crobaugh Co.*

895. Testing Machines

12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

896. Thermocouples

Chart of temperature-millivolt conversion tables for thermocouples. *Therma Electric*

897. Thickness Tester

Bulletin 400 on electronic testers for determining plating thickness. Applications of various models. *Kocour Co.*

898. Titanium

36-page booklet on how titanium is made, the advantages of titanium, corrosion properties and specifications of the various alloys. *Harvey Aluminum*

899. Titanium Alloy

11-page data sheet on MST881 contains 9 pages of charts and tables. Mechanical and working properties. *Mallory-Sharon Metals Corp.*

900. Titanium Wire

Conversion table for titanium wire and rod converts diameter sizes to feet per pound or pounds per foot. *Johnston & Funk Titanium*

901. Tool Steel

New 10-page Booklet 458 on general purpose tool steel. Analysis, uses, characteristics, wear resistance. *Bethlehem Steel*

902. Tool Steel

Chart gives stock sizes, analyses and properties of A2 and O1 precision ground tool steel. *Uddeholm*

903. Tool Steel

New 12-page brochure on low-temperature air-hardening tool and die steel. Fatigue properties, response to heat treatment. *Universal-Cyclops*

904. Torsion Testers

New 8-page Bulletin RT-10-54 gives details of construction, pendulum-type testers, torsion testers for wire. *Riehle*

905. Torsion Testing

10-page Bulletin 58 describes torsion testing machines and gives principle of operation. Recording system. *Tinius Olsen*

906. Ultra Strength Steel

Results of three-year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

907. Ultrasonic Cleaning

New 24-page Bulletin S-200 explains practical applications and basic principles of ultrasonic cleaning. Design of equipment. *Branson*

908. Vacuum Furnace

6-page data sheets on high-vacuum furnace for operation at 3600° F. Specifications and operating characteristics. *Richard D. Brew & Co.*

909. Vacuum Gages

New technical data sheet on vacuum thermocouple gage. Applications, operating instructions, physical and operational specifications and calibration curves. *NRC Equipment Corp.*

910. Vacuum Furnaces

Data on high-temperature high-vacuum retort furnaces. *General Vacuum Corp.*

911. Vacuum Melted Alloys

New 8-page Engineering Data Brochure VM-103 on vacuum-melted alloys. Comparison of air and vacuum melting. Uses. *Metallurgical Products Dept., G.E. Co.*

912. Welding

New 32-page catalog of welding products and guide to welding practice. Stainless, low-alloy, nonferrous rods and electrodes for manual, automatic and semi-automatic welding. *Arcos Corp.*

913. Welding

New 12-page Pamphlet 2004 Ea on automatic flash welding machines. Advantages, applications. *ASEA Electric, Inc.*

914. Wire Cloth

No. 3 of the Cambridge Wire gives applications of wire cloth in ceramics, metalworking, food, chemical and other industries. *Cambridge Wire Cloth*

915. Zinc Coating

8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

APRIL, 1959

657	681	705	729	753	777	801	825	849	873	897
658	682	706	730	754	778	802	826	850	874	898
659	683	707	731	755	779	803	827	851	875	899
660	684	708	732	756	780	804	828	852	876	900
661	685	709	733	757	781	805	829	853	877	901
662	686	710	734	758	782	806	830	854	878	902
663	687	711	735	759	783	807	831	855	879	903
664	688	712	736	760	784	808	832	856	880	904
665	689	713	737	761	785	809	833	857	881	905
666	690	714	738	762	786	810	834	858	882	906
667	691	715	739	763	787	811	835	859	883	907
668	692	716	740	764	788	812	836	860	884	908
669	693	717	741	765	789	813	837	861	885	909
670	694	718	742	766	790	814	838	862	886	910
671	695	719	743	767	791	815	839	863	887	911
672	696	720	744	768	792	816	840	864	888	912
673	697	721	745	769	793	817	841	865	889	913
674	698	722	746	770	794	818	842	866	890	914
675	699	723	747	771	795	819	843	867	891	915
676	700	724	748	772	796	820	844	868	892	
677	701	725	749	773	797	821	845	869	893	
678	702	726	750	774	798	822	846	870	894	
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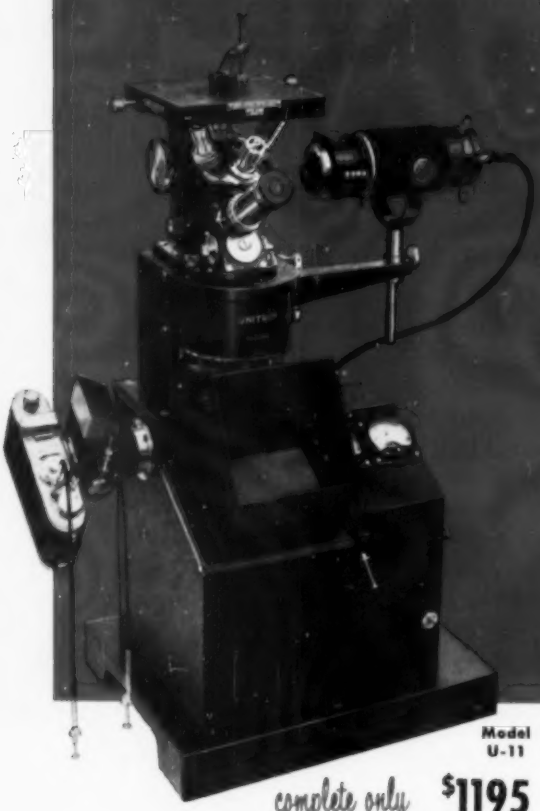

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UNITRON INVERTED Metallurgical Microscope, Model MEC: Many of the features of the UNITRON Metallograph U-11, which are connected with visual observation of opaque specimens, are included in this compact unit. Think of the time which can be saved in your laboratory by providing each metallurgist with one of these handy, inexpensive units for use at his desk. Model MEC is also ideal for use together with a polisher or microhardness tester.

- Standard optics include 4 parfocal objective lenses: 5X, 10X, 40X, 100X oil immersion on revolving nosepiece; 3 eyepieces: P5X, Micrometer 10X, Ke15X, all coated. Magnification range 25-1500X.
- Vertical illuminator with iris diaphragm. Transformer housed in microscope base. A microswitch on the base provides an extra high intensity for photography.
- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.

THIS COMPLETE CATALOG ON UNITRON MICROSCOPES IS YOURS FOR THE ASKING

FREE 10 DAY TRIAL on any UNITRON MICROSCOPES . . .

Let the instrument prove its value to you — in your own laboratory — before you decide to purchase.

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO
204-206 MILK STREET - BOSTON 9, MASS.

Please send me your complete catalog on UNITRON Microscopes. 2-P
Name and Title _____
Company _____
Address _____
City _____ State _____

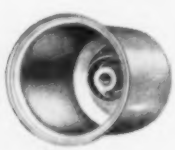
MUELLER BRASS CO. OFFERS 7 WAYS TO PRODUCE YOUR PART

Mueller Brass Co., because of its diversified manufacturing facilities that encompass a wide range of fabricating methods, is in the unique position of being able to offer you, the purchaser, an intelligent, unbiased analysis and recommendation of the best, most economical method by which your particular part can be produced. As the result of over 40 years' experience, the "Methods Analysis Department" has at its command complete knowledge of the advantages and limitations of each production process. After receiving detailed knowledge concerning the end use of the part, material specified, conditions under which it must operate and other pertinent factors, these analysis engineers make their recommendations. Every detail is considered. In many cases, methods analysis engineers recommend a simple design change that makes practical a much more economical method of production. This technical service, offered only by Mueller Brass Co., is given to each individual inquiry and is your assurance that you will get the best product at the best price . . . made the *one* best way . . . by Mueller Brass Co.

Send today for free technical literature on any one or all of the seven fabricating methods.

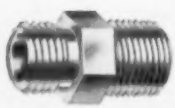
FORGINGS

Production equipment is available to produce press, hammer or cored forgings of any practical shape in sizes ranging from a few ounces to 150 lbs. in brass, bronze, aluminum and magnesium in 27 standard, as well as special, alloys.



COLD-PREST® IMPACT EXTRUSIONS

Mueller Brass Co. has complete machinery for producing Cold-Prest impact extrusions of aluminum, copper, brass, bronze and steel. Extrusions up to 28" in length are possible, depending on wall thickness and other design details. Parts can be designed having ribs, flutes, splines or bosses . . . with multiple wall diameters and with uniform or tapered wall sections.



SCREW MACHINE PRODUCTS

Mueller Brass Co. has one of the world's largest automatic screw machine departments fabricating both ferrous and non-ferrous custom parts. We can produce an infinite variety of shapes and sizes from ⅛" to 3¼" in wide range of free cutting and specialized alloys. Complete facilities for all secondary and finishing operations, as well.

POWDER METAL PARTS

Mueller Brass Co. can supply precision Sinteel® powder metal parts in wide range of sizes and metals at high production rate. Parts available from iron, brass and copper alloys. Parts may be ordered with such characteristics as self-lubrication, controlled porosity and good electrical and magnetic properties.

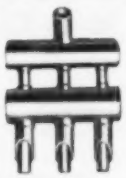
MADE IN U.S.A. TO THE STANDARDS OF AMERICAN INDUSTRY

MUELLER BRASS CO.

...and our methods analysis service helps you determine which is the best ...and most economical method

SAND CASTINGS

We specialize in the production of pressure-tight red brass castings. We utilize both metal match plate and wood patterns. Facilities include tool room and pattern shop, electric melting furnaces, high capacity core room and both bench and floor molding equipment to handle wide range of sizes.



FORMED COPPER TUBE

Mueller Brass Co. has modern facilities for forming seamless copper tube into a multitude of shapes. Forming methods used include bending, spinning, expanding or swedging, upsetting, flaring, flattening, beading and grooving, drilling and piercing, machining and joining. Formed copper tube coils are also available as single, double, spiral and serpentine shapes.

PLASTIC INJECTION MOLDING

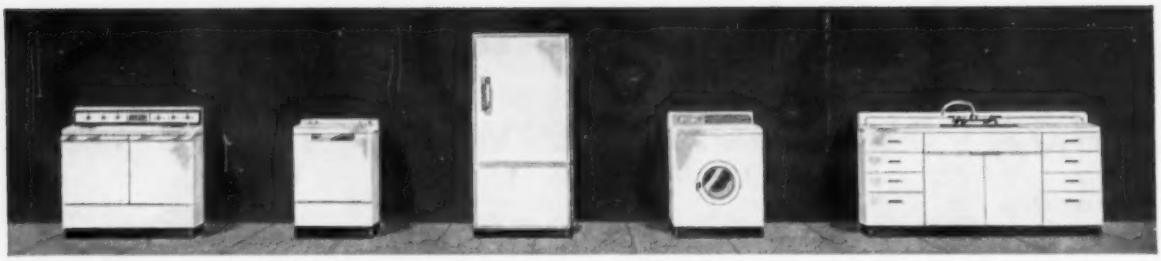
Injection molding of plastic parts is still another process offered by the Mueller Brass Co. Parts are molded from such plastics as—nylon, polyethylenes, polyvinyl chloride, styrenes, linear acetal, chlorinated polyether, polycarbonates or polypropylene, dependent on part application.

MAN FROM MUELLER BRASS CO.

Since only Mueller Brass Co. can produce your part by all the methods, only the Man From Mueller Brass Co. can give sound advice on the one best method of production. Over 40 years of research, engineering, manufacturing and marketing experience stands behind him. When you are specifying and purchasing fabricated metal parts, call in the MAN FROM MUELLER BRASS CO.

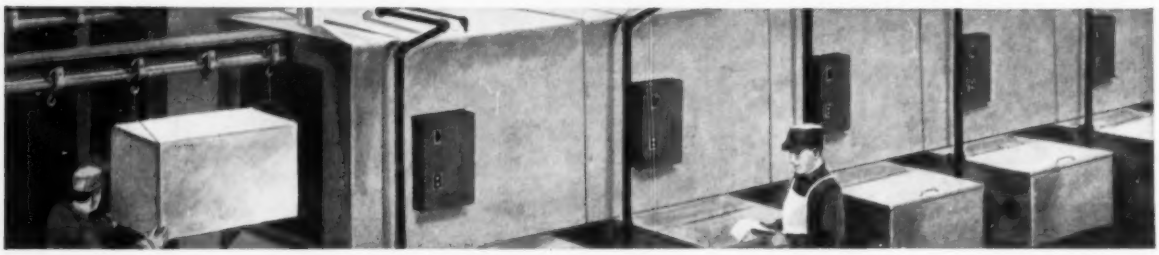
271

PORT HURON 28, MICHIGAN



PRODUCT PROTECTION

MEANS CUSTOMER SATISFACTION



WITH AMCHEM GRANODINE

Mechanical and electrical performance notwithstanding, the external appearance of appliance products weighs heavily in determining continued brand preferences.

That is why many major appliance producers have insisted upon the use of Amchem Granodine as a durable base for paint finishes. This efficient chemical solution ideally converts metallic surfaces to a nonmetallic phosphate coating of the proper texture, acts as a reliable inhibitor of corrosion while greatly increasing the adhesion and durability of the paint finish.

You'll find Amchem Granodine an economical and reliable method of providing that lasting protection so important to the future sale of your products . . . at a cost consistent with manufacturing budgets. And you can count on Amchem's complete technical and engineering service to keep Amchem chemicals working at the level of greatest efficiency in providing protection that lasts for the life of your product.

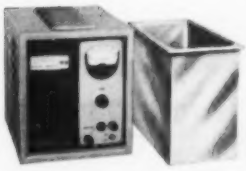
Shown above is typical Amchem power spray system for chemically treating steel products.

Write for Bulletin 1380A with handy Selection Chart to help you choose proper Granodine type for your specific needs. Also available are bulletins describing other Amchem chemicals for use in appliance manufacturing.

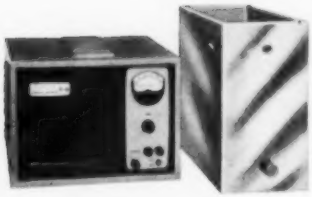
AMCHEM GRANODINE

Amchem Granodine is another chemical development of **Amchem Products, Inc.**, Ambler, Pa. • Formerly American Chemical Paint Company Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont./Amchem and Granodine are registered trademarks of Amchem Products, Inc.

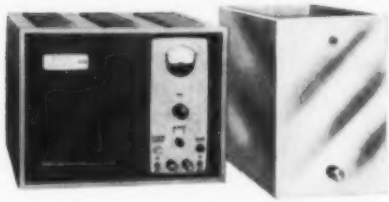
CIRCOSONIC®



Model BC 60
Capacity - 1 gal.
output - 60 watts



Model BC 125
Capacity - 2 gal.
output - 125 watts

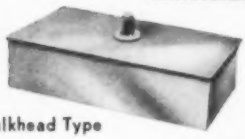


Model BC 250
Capacity - 5 gal.
output - 250 watts

ultrasonic
multi-purpose cleaners

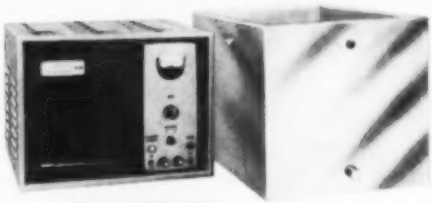
by the most experienced company in the application of ultrasonic energy for metal cleaning.

Immersible Transducers



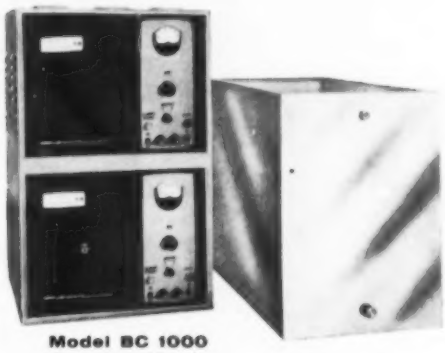
Bulkhead Type

End Type



Model BC 500
Capacity - 12 gal.
output - 500 watts

White Room Cleaning Units



Model BC 1000
Capacity - 25 gal.
output - 1000 watts

THE CIRCOSONIC POWER CONCEPT

The magic word "ultrasonics" alone is not enough. To accomplish the results for American industry, sufficient driving **Power** must be applied to a **Precisely Designed Transducer** at the correct **Frequency** — consistently. This concept of **Power** ultrasonics is embodied in **Circosonic.** Only **Circo** meets these requirements, combined with trouble free continuous operation and economical purchase cost.

Solid stainless steel is used in cleaner tank manufacture making them suitable for all type liquids. Controls are conveniently placed and identified for ease of operation by unskilled personnel.

From the first ultrasonic cleaning machine publicly operated at the National Metal Congress at Philadelphia in 1952, to the new **BC** Series, **Circo** has consistently demonstrated its leadership in the design and application of ultrasonic energy.

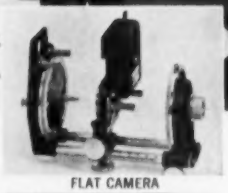
Commercial units in operation range from small laboratory models to huge conveyorized automatic units, handling up to 20,000 lbs. metal parts per hour. **Circo** engineers will be pleased to offer technical assistance and recommend specific units to fit your needs.

Send for our new booklet "Tips on Ultrasonic Cleaning."

CIRCO ultrasonic CORPORATION

Specialists in ultrasonic energy
51 TERMINAL AVENUE, CLARK NEW JERSEY

SCIENTIFIC INSTRUMENTS FOR RESEARCH AND DEVELOPMENT



FLAT CAMERA

CYLINDRICAL CAMERA

GUINIER CAMERA

STRESS CAMERA

STEREO-MICROCAMERA

NOW FOR AS LITTLE AS $4,000 !
Complete RCA X-Ray Diffraction Equipment for all Types of Film Studies

Think of it—a complete x-ray diffraction facility for film studies can be yours now for less than $4,000.00. A typical installation could include: a Crystalloflex II X-Ray Diffraction Generator complete with two powder cameras, a flat camera, and a stereo-microcamera, a copper target x-ray tube and camera carriers. Other combinations, with prices varying according to the selection, could include both one and two radian cylindrical cameras, flat cameras and the very versatile 70mm. film with one radian cylindrical camera which can be used for powder diffraction, symmetrical back reflection work and rotating crystal layer line diagrams. A wide variety of additional cameras, x-ray tubes with other targets, and attachments for special specimen handling are also available.

Cameras used with the Crystalloflex II can be operated simultaneously at four x-ray ports, each of which is equipped with an individually timed shutter. Rating of this compact table model is 25 to 60 KV in 5 KV steps. Tube current control is continuous from 0 to 40ma. Overall size of the unit is 24″ wide x 32″ high x 22″ deep. The Crystalloflex II can also be tilted so that the tube may be operated horizontally. All these features make this generator an excellent tool for chemists, metallurgists, physicists and biologists whose research projects usually entail a high volume and wide variety of film work.

RCA also offers the Crystalloflex IV console model generator, and the world's most complete line of attachments and accessories for x-ray diffraction and spectroscopy including an exceptionally versatile group of cameras, pole figure goniometer, single crystal layer line and microfluorescence attachments.

Contract services on RCA X-Ray diffraction equipment and electron microscopes are available through eleven regional offices of the RCA Service Company.

For more information about this advanced equipment or a quotation on your requirements, write: Radio Corporation of America, Dept. S-72, Building 15-1, Camden, N.J.

RADIO CORPORATION of AMERICA
CAMDEN 2, N. J.

"WEIRKOTE® WON'T PEEL OR FLAKE—AND CAN END THE NEED FOR FURTHER CORROSION PROTECTION AFTER FABRICATION."

Q. A zinc-coated steel sheet that won't peel or flake, even under the severest fabricating stresses?

A. Precisely. Weirkote's made by a continuous process. The zinc is so integrated with the steel that even the toughest "torture" tests of fabrication leave that bonded coating intact. You can work Weirkote to the very limits of the steel itself!

Q. Our products are pretty intricate—take lots of flexing, crimping and so on. What about those hard-to-reach places?

A. Weirkote's zinc coating is so uniform—protects even the most complicated parts.

Q. So with Weirkote you bypass the need for further corrosion protection?

A. You get the picture! Think of the time, labor, space—the costly capital outlay—you save. Better steel products at far lower costs—that's Weirkote for you!

Send for free booklet that details the time-and-cost-saving advantages of skin-tight zinc-coated Weirkote. Just write Weirton Steel Company, Dept. S-2, Weirton, West Virginia.

WEIRTON STEEL COMPANY

WEIRTON, WEST VIRGINIA

a division of

NATIONAL STEEL CORPORATION

Here's How to Cut Contact Costs... Maintain High Performance Quality...

Use General Plate Clad Contact Materials

Among the many advantages in using General Plate Clad Contact Materials are better electrical performance, longer operating life and lower fabricating costs.

Single and double inlay, overlay and toplay make it possible to manufacture complete contact assemblies to close tolerances by single blanking and forming operations. Compare this to multiple operations whereby the contacts and supporting members are fabricated separately and then assembled by brazing, welding or staking methods and you readily see the savings in production costs alone.

But that's not all . . . here at General Plate we specialize in supplying you with complete fabricated clad contact assemblies ready for installation. They will save you money, time and trouble . . . problems of precious metal inventory and scrap disposal are eliminated.

Why not find out how you can cut costs, increase performance with General Plate Clad Contact Materials and fabricated assemblies. Write:

You Can Profit By Using General Plate Clad Contact Materials

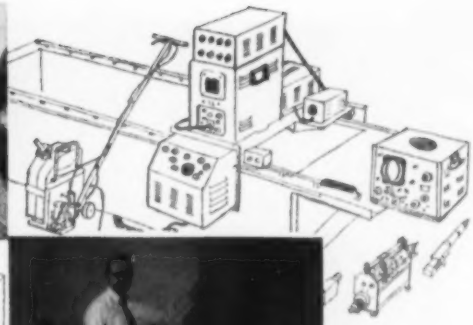
Typical example of how General Plate Clad single and double inlay reduces fabrication and assembly costs by simple one-step stamping.

METALS & CONTROLS CORPORATION

General Plate Division

304 Forest St., Attleboro, Mass.

FIELD OFFICES: NEW YORK • CHICAGO • DETROIT • INDIANAPOLIS • MILWAUKEE • PASADENA



in ULTRASONIC TESTING

only SPERRY offers you such a wide range of Services, Instruments and Accessories

When you consider Ultrasonic Testing *be sure to consider the services.* Sperry's 14 years of proven performance to industry has produced a *complete range* of services for you:

SPERRY RESEARCH AND DEVELOPMENT SERVICE — diversified investigations into testing problems for government and industry.

SPERRY APPLICATION RESEARCH SERVICE — ready to help solve your specific testing problems with the most advanced techniques.

SPERRY SPECIAL SEARCH UNIT DEVELOPMENT SERVICE — the design of special search units and auxiliary equipment to meet your testing requirements.

SPERRY CUSTOM INSTALLATION SERVICE — design and manufacture of tailor-made inspection installations . . . from simple, manually-operated to automatic systems.

SPERRY COMMERICAL TESTING SERVICE — Sperry's engineers will do the testing *for you* on a day-to-day basis at your plant or in one of our laboratories.

SPERRY SCHOOLS OF ULTRASONIC TESTING — held at convenient locations throughout the country for industrial and government personnel.

30 years specializing in nondestructive flaw detection

For technical service or information, write . . .

Sperry

REFLECTOSCOPE

ULTRASONIC TESTING EQUIPMENT

SPERRY PRODUCTS, INC., 504 Shelter Rock Rd., Danbury, Conn.

INDUCTOMELTING MEANS*

FEWER CASTING REJECTS

The application of INDUCTOMELTING in ferrous and non-ferrous foundries assures fewer faulty castings. Several related factors contribute to this reduction of rejects . . . such as Inducto's high melting speeds, precise temperature control, electromagnetic stirring action and virtual freedom from gases and slag particles.

Consider the effect of these characteristics on your castings. The melting speeds are so high that oxidation and metal losses are insignificant. Correct pouring temperatures are always achieved—easily—and heat after heat can be exactly duplicated. You maintain close control over melt history. Critical alloys are not lost due to prolonged or excessive heating. Accurate control of alloy chemistry is assured since losses are negligible, even in the more easily oxidized metals. All melts are homogeneous because of the electromagnetic stirring action induced by the furnace. Carbon is not a problem and gas content can be held to a bare minimum.

These factors clearly explain why INDUCTOMELTING contributes to a sharp reduction in casting rejects. Add these savings to low metal losses, efficient operation and faster production and you can readily see how modern Inducto melting equipment has saved more than its cost in many installations over a short period of time.

Write for complete details as outlined in Bulletin 70. Inductotherm Corporation, 412 Illinois Ave., Delanco , N. J.

**INDUCTOMELTING is high-frequency induction melting PLUS the additional advantages of INDUCTO design features and engineering techniques.*

INDUCTOTHERM

INDUCTO . . . the mark of modern melting

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

Lehigh H makes deep draw... passes test with flying colors

It takes a deep draw to form these cone-shaped lamp shades from .025 in. steel sheet at Keystone Lamp Manufacturing Co., Slatington, Pa. The forming die frequently gave trouble, causing production to bog down.

The lamp maker contacted Luria Steel Supply Co., a distributor of Bethlehem tool steel. "We know the job is difficult," they said, "but perhaps you can tell us about a tool steel that will withstand such a deep draw."

The Luria representative had seen such problems before. "I'd recommend Lehigh H," he told them. "I've seen it handle plenty of tough applications. It has all the stamina you need for this job, and then some."

The Lehigh H die, hardened to Rockwell C60, performed just as he said it would. It had high surface hardness to prevent pickup and galling. Because of its high wear-resistance, it averaged 200,000 shades, a substantial increase. Only .010 in. had to be removed when redressing was necessary.

Lehigh H (AISI D-2) is our standard high-carbon, high-chromium grade of air-hardening tool steel. It is a deep-hardening grade with high compressive strength. It has high wear-resistance, plenty of toughness, and minimum size change during heat-treatment — the characteristics you need most for maximum production.

TYPICAL ANALYSIS

Carbon 1.55 Chromium 11.50 Molybdenum 0.80
Manganese 0.40 Vanadium 0.90

The best way to appreciate the advantages of Lehigh H is to put it to work. A trial run in your shop can be arranged by your local Bethlehem tool steel distributor.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

You Can Remedy Fatigue-Failures

Chisels and other tools which are subjected to repeated stresses often fail suddenly. Because these tools are made from shock-resisting steel, the sudden failures can appear mysterious. However, close inspection of the failed parts often reveals that the failures were not sudden at all. They occurred because a crack progressed part way through the section, followed by sudden fracture of the remaining section.

Fatigue-fractures have a characteristic, smooth-rubbed surface where the initial crack opened up, plus an inner crystalline zone revealed by the final sudden break. Often the smooth-rubbed surface shows parallel "oyster-shell" markings, and sometimes, evidence of rusting.

As a rule, fatigue-failures begin at a stress-concentration point, such as a notch, a poor fillet, tool mark, accidental nick, or deep stamping. The proper cure is to correct such design or mechanical faults promptly.

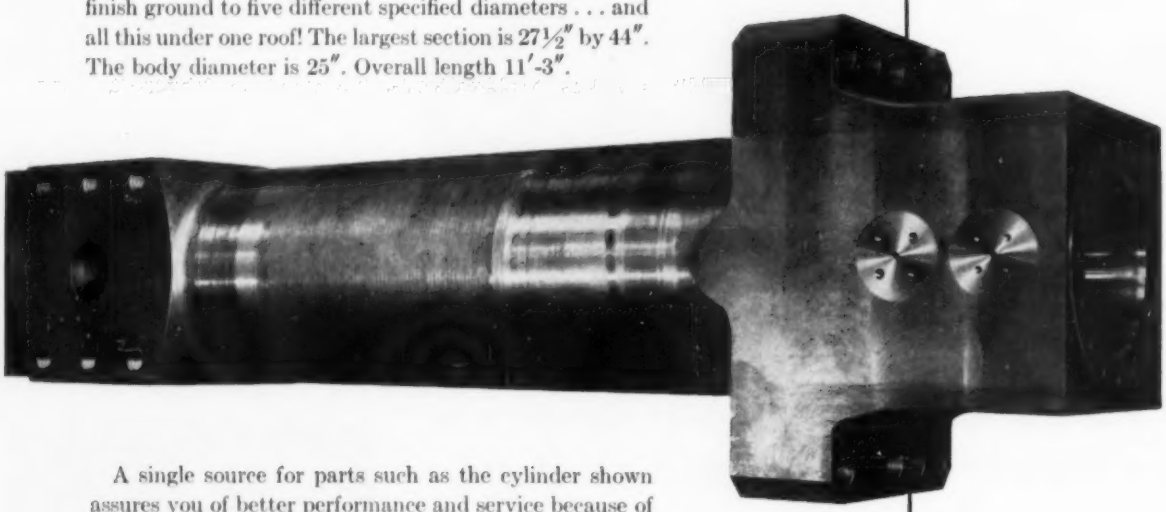
USE UPSET-FORGED DISCS FOR ALUMINUM EXTRUSIONS TOOLING

Bethlehem produces a full line of upset-forged discs for the manufacture of dies for aluminum extrusions. The discs are forged by expert hammer crews. They are finished in ring dies to insure good section. You can choose from two grades of tool steel—Cromo-WV, chrome-moly-tungsten-vanadium (H-12), and Cromo-High V, chrome-moly-high vanadium (H-13). Each grade has good resistance to erosion and heat-checking.

"Forgings by Finkl"

...from blueprint to finished part

This is a side cylinder for a hydraulic press. It was made from a Finkl C 1035 electric furnace steel forging weighing 32,000 pounds. When shipped it weighed 14,850 pounds. Between the start and finish it had been heat treated, milled, turned, tapped, and the inside bored and finish ground to five different specified diameters . . . and all this under one roof! The largest section is 27½″ by 44″. The body diameter is 25″. Overall length 11′-3″.



A single source for parts such as the cylinder shown assures you of better performance and service because of greater quality control through each step of its processing.

"Forgings by Finkl" is synonymous with highest quality. Finkl custom forgings have the stamina and fatigue resistance to withstand the severe strains and torsional stresses encountered in modern heavy duty machinery. We also produce repair parts for all types of forging equipment; containers, liners, and plungers for extrusion presses; plastic molds; and die casting steels.

Next time you are thinking of forgings, think of Finkl. The best costs the least in the long run.

DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

F

A. Finkl & Sons Co.

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Mail this coupon today to find out how

The Denver Fire Clay Co.
3033 Blake Street
Denver, Colorado
Please send full information on the DFC line of industrial furnaces.

Name .....
Address .....
City .....

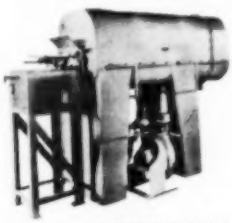
Denver Fire Clay builds Better Furnaces for Industry

Special Car Bottom, Heat Treating Furnaces

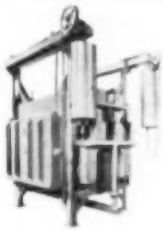
The Denver Fire Clay Company designs and supervises the construction of special car bottom, heat treating furnaces to your requirements.

The efficient design of each furnace is assured by many years of experience in the manufacture of industrial furnaces. Constructions for heat treating carbon steel, manganese steel and malleable iron castings; also for stress relieving welded steel assemblies and forgings.

Prerequisites of **every** DFC Furnace design are **Simplicity, Durability** and **Efficiency.** Let our engineering staff help with your heat treating problem.



SHAKER HEARTH
HEAT TREATING FURNACE



BOX TYPE
HEAT TREATING FURNACE

SEMI-MUFFLE TYPE
HEAT TREATING FURNACE

Denver Fire Clay Company

DENVER • SALT LAKE CITY • EL PASO

DF 9-7

Castings of

ARMASTEEL®

so tough they replace forgings so machinable...they reduce finishing costs

CLASSIFICATION	CHARACTERISTICS	HARDNESS (BHN)	MIN. TENSILE STRENGTH (PSI)	MIN. YIELD STRENGTH (PSI)	MIN. % ELONGATION IN 2 INCHES
ARMASTEEL GM 86M	Recommended for less highly stressed parts. Replaces steel parts in 1020-1035 S.A.E. range.	163-207	70,000	48,000	4.0
ARMASTEEL GM 85M	Recommended for moderate strength plus adaptability to selective hardening. Replaces parts in 1035-1050 S.A.E. range.	197-241	80,000	60,000	3.0
ARMASTEEL GM 84M	Recommended for high degree of strength. Replaces heat-treated parts in 1040-1050 S.A.E. range.	241-269	100,000	80,000	2.0
ARMASTEEL GM 88M	High resistance to wear and high yield strength, yet retains machinability. Requires no heat-treating and possesses some strength and wear characteristics as alloy steel forgings.	269-302	105,000	85,000	2.0

CENTRAL FOUNDRY DIVISION

Because ARMASTEEL castings are so machinable, so resistant to wear and shock, and so adaptable to selective hardening, they are rapidly replacing many parts formerly machined from bar stock or steel forgings.

ARMASTEEL, a pearlitic malleable iron, possesses the same strength and performance characteristics usually associated with plain carbon steel. In addition, ARMASTEEL contains excellent bearing properties, has high yield strength, good damping capacity, maximum rigidity and excellent fatigue life. Accurate control of heat-treating operations in the manufacture of ARMASTEEL produces a fine, uniform grain structure and provides excellent finishing qualities.

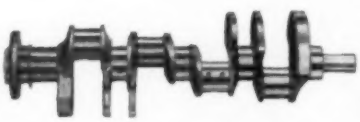
Four different types of ARMASTEEL can be cast to your specifications. One of the four (GM 84M, GM 85M, GM 86M or GM 88M) will have the physical properties to best meet the requirements of your application. For example, ARMASTEEL castings are being successfully used in the automotive, appliance and implement fields for such parts as gears, pistons, crankshafts, rocker arms and universal joint yokes, all of which utilize to best advantage the outstanding characteristics of ARMASTEEL.

Some of these applications are shown in the table. Look them over carefully; you may find that these characteristics and advantages of ARMASTEEL can help reduce your costs . . . increase your production . . . and improve the performance of your products.

Typical ARMASTEEL castings

Because of the greater physical properties of GM 86M ARMASTEEL, it was possible to redesign this anchor plate as shown and effect a weight reduction from 2.26# per piece to 1.44# per piece.

GM 86M ARMASTEEL provides the ideal casting for this automobile differential case because of its high strength, minimum deflection and good damping qualities which contribute to quietness of operation. Note the as-cast internal cavity and the well-formed webs.



GM 85M ARMASTEEL provides a crankshaft with more desirable machining characteristics than a forged crankshaft of SAE 1045 steel. Improves machining of journals and reduces checking stock. Use of GM 85M ARMASTEEL made possible the redesign of the crankshaft with a resulting 3.5# weight reduction and a lower material cost.

By converting to GM 85M ARMASTEEL, drilling and boring operations were eliminated on this crankshaft sprocket. Stock in rough part was reduced from 1.93# in forging to 1.00# in casting. Customer realized reduced piece price with GM 85M ARMASTEEL.

GM 84M ARMASTEEL was specified for this socket plate journal because its microstructure makes it more easily machined than steel with the same physical properties. It has better bearing and wear resistance qualities . . . less distortion during machining . . . and does not require heat treatment. Weight of part in rough is less than comparable steel forging.

Crankshaft for newly designed small gasoline engine. GM 84M ARMASTEEL specified because of outstanding success in similar engines. Less stock removal and better machinability are advantages over forged crankshaft.

This planet gear carrier was formerly forged from SAE 1141 steel, which required a heat treatment after rough machining and broaching operations. By converting to GM 88M ARMASTEEL, heat treatment was eliminated and the weight of the rough part was reduced.

By converting to GM 88M ARMASTEEL for this universal joint yoke, hole thru hub could be cast in . . . eliminating a drilling operation and reducing weight of part approximately 30%. GM 88M ARMASTEEL part has lower piece price than forging formerly used.

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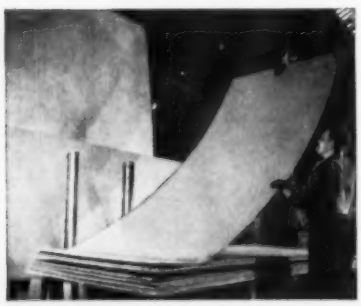

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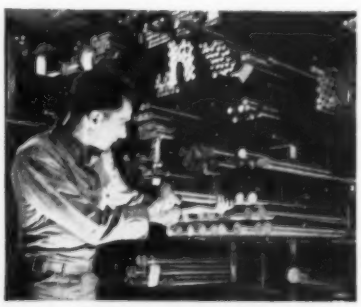

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Metal Progress
Vol. 75, No. 4 April 1959

Critical Point

"Unbreakable" Ships in a Hurry?

A COUPLE OF YEARS AGO the Editor-in-Chief was looking over the annual report of the National Research Council and noted that its Committee on Ship Steel, after some six years of existence, was being reorganized "to provide some of the members of long standing with a respite from their committee duties and to bring different backgrounds to bear on the problems facing the committee". He interpreted this as a polite way of saying that the old committee had gone about as far as it could along the lines it had been pursuing, and concluded therefore that *Metal Progress* should summarize the achievements up to that milestone, and perhaps indicate some of the work to be done in the future.

He found that two interpretative reports were actually under preparation – one of book length. When he examined them, he was left with a rather discouraged feeling that if we ever had to build a lot of ships in a hurry we would probably run into trouble again. Granted that most of the brittle failures in dry-cargo "Liberty" ships and the "Victory" ships were due to readily corrected errors in design, the all-welded tankers are still developing plenty of troubles in members thicker than 1 in. Apparently tough plate of this sort can be made of killed steel, but the American plate makers are not equipped to cast and roll such big-end-up, hot-top, slab ingots in sufficient quantity for a lot of ships in a short time.

In the present issue is an article resulting from these editorial doubts. Messrs. Harris and Williams have analyzed the evidence and believe that steels made according to the American Bureau of Shipping's revised specifications dated Jan. 31, 1956, will reduce brittle fracture in ship service to a vanishing point, *except* that thicker plates cannot be made of killed steel in our existing steel mills. For these thick plates they recommend semikilled steel somewhat lower in carbon and higher in manganese than required by the present standards.

Even though one may discount the idea that we will run into another wartime emergency lasting four or five years (any next World War will be over in that many weeks and will be fought with men and materials instantly available), we certainly should not be content to place anything but the best steel in American ships. "You American engineers are a strange breed!" said Professor Week of Cambridge University in this connection during his recent Seminar on Residual Stress. "You take foolhardy chances in traveling by automobile, yet you worry a great deal about the vanishing chance of accidents to ocean shipping!" The only reply to him was, "Maybe so. We admit that perfection is unattainable by human beings. Yet we must constantly try to achieve it." (I think the British do too!) E.E.T.

Fig. 1 — Failure at Sea of T/2 Tanker

Tough Ship Plate

By WILLIAM J. HARRIS, JR.
*and CLYDE WILLIAMS**

A review of the enormous amount of work done since 1946 by the Ship Structure Committee leads to the conclusion that a vanishing number of failures need be expected in normal service of welded ships properly designed and constructed of steels meeting the revised specifications of the American Bureau of Shipping. (Q26s, T22g; ST, 4-53, 7-51)

IT IS WELL KNOWN among engineers that catastrophic failures of all-welded merchant ships and tankers occurred unexpectedly during World War II. In retrospect, it is evident that a long series of earlier brittle failures of steel structures should have given notice of the difficulties that might be encountered in all-welded ships. In 1942, however, no summary and analysis of previous failures was available.

Since that date, continuous attention has been

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The study summarized in this article was made under the auspices of the Committee on Ship Steel through a contract between the Bureau of Ships and Battelle Memorial Institute. The study was fully reported in Ship Structure Committee Report SSC-80. Much of this study is based on experimental work performed at the National Bureau of Standards on specimens taken from failed ships.

given to the brittle fracture problem. As a result of effective coordination of a variety of investigations, more is now known about the cause and nature of ship failures than about accidents involving any other type of large structures. The mechanical properties of plate taken from ships which have failed have been determined. The manufacture of ship steel has been closely scrutinized. Many research projects on the metallurgical and mechanical factors which influence the brittleness of steel have been completed; others are still being prosecuted.

As a result, much progress has been made toward an engineering solution of the problem of brittle fracture in ships. Improved design and fabrication practices are now incorporated into new ship construction. Better steels made under revised specifications of the American Bureau of Shipping have been in use since 1947, and further improvements are now being made, directed by completed research projects which have pointed the way toward the control of notch toughness of ship plate.

Ship failures obviously involve a wide variety of incidents, including collisions, groundings, and severe storms. Some brittle fractures had occurred in riveted steel ships, but the crack usually progressed through only one plate and stopped in a rivet hole or at a riveted seam. The much more continuous structure of a welded ship allowed the crack to progress through many plates until it was stopped by lack of energy for propagation or by some barrier such as tough steel or a structural discontinuity.

The Performance Record – Data on the rate of failures of World War II ships are given in Table I for two classes of dry-cargo ships, the "Liberty" ships and the "Victory" ships, and one class of tanker, the T-2 tanker. The data are based on records of service performance of all vessels of the indicated types from the date at which the first vessel started on its first voyage up to and including March of 1953. "Group I Casualties" are those wherein one or more fractures have so weakened the hull that the ship was lost or placed in a dangerous condition. A "Group II Casualty" refers to a ship having one or more potentially dangerous fractures, generally less than 10 ft. long, in the hull.

In Liberty ships a marked reduction in failure rate resulted from redesigning the hatch corners and other critical locations to reduce local stress concentrations, and from improving the quality of the welds. These improvements cut the casualty rate by 80%.

The Victory ship represented a later design of a faster vessel carrying dry cargo. Its casualty rate was cut a further 80% by improved details and fabrication practices incorporated at the very beginning. It can thus be seen that the high accident rate of the first Liberty ships had been cut by 96% (from 195.5 casualties per 1000 ship-years to 7.4) by early, logical and fairly simple means. On this last 4% of the trouble has been expended about $3,500,000 worth of investigation – a tidy sum, but actually only about half the cost of a single ship without cargo. The results have pointed the way to elimination of even this last 4% of failures.

Equal success was not achieved in the tanker program, as shown in the last two lines of Table I. Some modifications were introduced in the all-welded T-2 tanker (such as the addition of riveted straps that interrupted the con-

Table I – Record of Casualties

Type of Ship	Ship-Years of Service	Group I Casualties	Group I Casualties Per 1000 Ship-Years	Group II Casualties	Group II Casualties Per 1000 Ship-Years	Combined Group I and II Casualty Rate
EC-2 (Liberty ships)						
1. All-welded with original details	2100	88	41.8	320	153.7	195.5
2. All-welded seams, improved details and some riveting	7303	40	5.5	214	29.3	34.8
VC-2 (Victory ships)	2695	4	1.5	16	5.9	7.4
T-2 (Tanker)						
1. All-welded	1483	28	18.9	69	46.4	65.3
2. All-welded with riveted straps	2064	25	12.1	94	45.5	57.6

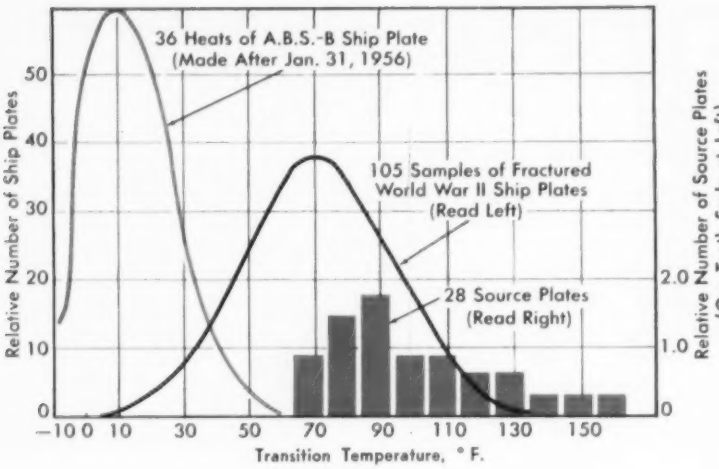

Fig. 2 — Distribution Curves of Transition Temperatures of ¾-In. Ship Plate of Three Varieties — 28 Plates Wherein Catastrophic Fractures Occurred in Welded World War II Ships; 105 Source-Plates, Through - Plates, and End - Plates From World War II Ships; 36 Heats of A.B.S.-B Ship Plate Melted Recently. Note that highest transition temperature of the modern steel is lower than the lowest transition temperature in the source plates in which fracture started in a World War II ship

tinuity of the structure and which were expected to serve as crack arrestors). Although the severity of cracking was somewhat reduced by the crack arrestor, the rate of failure was changed but little as shown by comparing the last two lines of the table.

In summary it may be said that, despite extensive structural alterations, brittle fractures in dry-cargo ships and in tankers were not eliminated during World War II. However, the present authors believe that in the last decade, action has been taken to insure against a repetition of the ship failures of the last emergency, particularly in the Group I category that result in loss or endanger the ship.

Conditions Required for Brittle Fracture — It is now clear that brittle fractures in ships occur when three conditions exist:

First, a sufficiently high stress must be present. The rate of failure in World War II was many times as great under the stresses imposed in heavy seas than under the lower stresses in port. However, in port the low applied stresses, perhaps combined with thermal stresses from differential air and water temperatures or sunshine, and residual tensile stresses* introduced during fabrication, were great enough to cause some failures.

Second, a notch serving to concentrate the stresses must be present. Notches that gave trouble took the form of square corners in hull openings, and fabrication defects such as cracks or voids in poor welds. Some failures were associated with a defective weldment or an arc strike, often acting in conjunction with a structural discontinuity.

Third, to avoid failure the steel must be able to deform rather than to crack at the root of the notch at service temperatures. Much attention has been given to means of measuring this ability of steels to deform rather than to crack — that is, to measuring its "notch toughness".

Corrective Measures — It is obvious from this analysis of the problem that corrective measures must be taken in all three factors — (*a*) design, (*b*) fabrication and (*c*) metallurgical quality.

Reducing the stress level below the value at which brittle cracks will propagate does not appear to be an acceptable solution to the ship failure problem. It is always possible that the design loads will be exceeded some place or other when the ship is battling heavy seas.

Again, while the incidence of brittle failures in service has been reduced by improving the design and fabrication practices, *complete* elimination of notches is impossible even in the original construction. Furthermore, ships are often modified and altered while in service; this gives many more chances for introducing sharp notches or cracks. Flawless design and fabrication is as improbable in shipbuilding as perfection in any other human activity.

This brings us to the third item — metallurgical quality, in which readers of *Metal Progress* are vitally interested.

When ships started to fail in a brittle manner, it was generally assumed that the ductility of the steel was below specification. However,

*Residual stresses are those which exist in a structure at uniform temperature when no outside force is acting. Locked-up tensile stresses as high as 47,000 psi. have been found in welded ship structures.

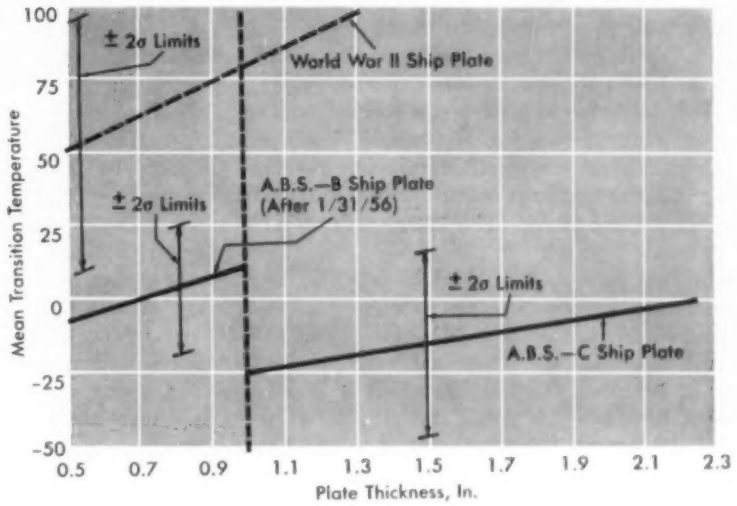

Fig. 3 – Trend of Transition Temperature With Plate Thickness for Three Classes of Ship Plate (Standard Deviations Indicated). Transition temperature is where Charpy V-notch sample absorbs 15 ft-lb. of energy

samples of the failed plates showed that the metal conformed in every respect to the applicable specifications, having an average yield strength of 35,000 psi., tensile strength of 62,000 psi., elongation of 35% in 2 in. and 58% reduction of area in a standard tensile test. Contrary to this evidence, inspection of the fractured plates revealed that very little plastic deformation had occurred and that the actual failures were of a brittle nature, certainly incompatible with the good ductility shown in the tensile test.

Such findings led to the study of the notch toughness of the steels, a property not covered by specification, by performing Charpy V-notch impact tests over a range of temperatures.

The fractured plates taken from the ships were divided into three groups – (*a*) plates containing the *source* of the fracture – that is, the "source plates", (*b*) those through which the fracture propagated – the "through plates", and (*c*) those containing the *end* of the fracture – the "end plates". The National Bureau of Standards studied 28 source plates, 45 through plates and 32 end plates, and found that the average transition temperature* of the three classes was 96.4, 66.1 and 51.5° F., respectively. This is a revealing fact indeed, and the idea that high impact value at low temperature is most desirable is reinforced by the data plotted in Fig. 2. The blocks at lower right show the distribution for the 28 source plates, while the curve with peak at 70° F. is the distribution for the whole group of 105 plates.

*Transition temperature is the temperature where the Charpy V-notch impact value equals 15 ft-lb.

All of these plates which contained the source of fracture had transition temperatures of 60° F. or higher. No source plate absorbed more than 11.4 ft-lb. at the temperature at which failure in the ship occurred, while most of the end plates containing the end of the fracture had higher notch toughness at the failure temperature. From this and other evidence it is reasonable to assume that use of steel with greater notch toughness at the operating temperature (that is, a steel with a lower transition temperature) would reduce failure rates.

While there continues to be some controversy regarding the best test to represent notch toughness, the Charpy V-notch test at 15 ft-lb. appears to be acceptable for the ship failure problem in view of the correlations shown to exist between laboratory tests and service failure. If steels of widely differing classes are studied or if failures involving quite different circumstances are analyzed, it is necessary to review the test method and adjust it appropriately.

Improved Steels – It is satisfying to know that extended studies of the metallurgical qualities which promote toughness in steel have resulted in revised specifications for ship steel and its commercial production.

For a number of years prior to 1947 and including all the period during which our wartime shipbuilding program was under way, the American Bureau of Shipping's rules for structural steel for hulls contained no chemical requirements, merely stated that the steel should be made by the openhearth or electric furnace process. One tension test and one bending test were required

to be made from the finished material from each melt, but if the heat weighed more than 50,000 lb., a second set of tests was required.

The tensile strength for plates was required to be between the limits of 58,000 and 70,000 psi. The yield point was specified to be not less than one half the tensile strength and the minimum elongation in 8 in. was to be 1,500,000 divided by the tensile strength.

In 1947, new specifications came into effect, separating ship steel into three classes, A, B and C, depending on thickness. All classes had 0.04% max. phosphorus and 0.05% max. sulphur. Tensile specifications for all classes are the same; 58,000 to 71,000 psi. tensile strength, 32,000 psi. min. yield strength, 22% min. elongation in 2 in., and 21% in 8 in. Revisions to the specifications in 1956 slightly altered composition levels. A.B.S. Class B steel is for 0.5 to 1-in. plates and a more detailed chemical specification is imposed, namely, 0.21% max. carbon and 0.80 to 1.10% manganese. A.B.S. Class C steel is for 1-in. to 2-in. plates. Their carbon is 0.24% max., manganese 0.60 to 0.90% and silicon 0.15 to 0.30%, indicating a killed steel.

The curve at the left in Fig. 2 shows that the A.B.S. Class B ship steel has transition temperature about 60° below that of World War II plate, and Fig. 3 (which shows the relation between the thickness of present-day steel and its transition temperature) indicates that A.B.S. Class C ship steel is even better. We conclude that these steels should be resistant to brittle fracture in ship service. While it is conceivable that fracture could occur under extreme conditions of temperature and stress, the chance of such a failure in A.B.S. Class B and C steels appears to have been reduced almost to the vanishing point. This would seem to be a happy solution to this problem that rightly caused so much concern during World War II.

Manufacturing Problems — However, there remains one critical consideration. Ships are produced in peacetime, but also may be produced in quantity in case of a future mobilization effort of the type that occurred during World War II. In view of the great demand for materials in such an emergency, careful study must be given to the metallurgical factors that might influence the notch toughness of ship plate. Two of these emerge as the most critical:

Plate up to 1 in. thick may be made under present A.B.S. specifications using semikilled practice — that is to say, incompletely deoxidized so sufficient carbon monoxide to offset shrinkage is evolved during solidification. As a result, the yield of billet from ingot is high without requiring a hot top on the ingot mold. As far as steel mill facilities are concerned, it appears to the writers that semikilled steel plates could be produced by existing American steel mill facilities in sufficient quantity and of sufficiently low transition temperature to satisfy the requirements, and most ship steel has been around ¾ in. thick.

However, the requirement for killed steel for heavier plates introduces a serious problem. This requires big-end-up ingots with hot tops and special handling of the hot tops themselves. The big-end-up mold not only increases the cost of steelmaking, but also introduces a requirement for special facilities, such as areas in which ingot and mold can cool to permit stripping. At present, the American industry can make over 100,000,000 tons of steel per year, but only about 15,000,000 of this can be hot-topped. Furthermore, ship plates are rolled from slab ingots, not ingots of other configurations, and the facilities for making hot-topped *slab* ingots represent only a fraction of all hot-topping equipment.

Killed steel generally contains more silicon than semikilled steel and has a lower transition temperature for the same carbon and manganese contents and the same ferrite grain size. As noted above, killed steel is now specified and used for ship plate over 1 in. thick. It is also commonly used for products of the highest quality. During World War II, about 15,000,000 tons per year was produced for aircraft and ordnance forgings, ship armor, and other critical uses. Because the large increase in steelmaking capacity in the United States since 1945 has not been accompanied by a corresponding increase in facilities for making killed steel, a future emergency would find killed steel in great demand, and every effort should now be made to find safe ways of using semikilled steel in ships, because it is likely that killed steel would be diverted from ship plate.

At least one mill that produces ship plate in the United States is equipped to roll directly from ingots. Semikilled practice requires additional equipment for slabbing and surface conditioning. Under this circumstance, mills that roll directly from the ingot can now produce ship plate only of killed or rimmed steel.

Low Transition Temperature — A study has been made of the various methods of lowering

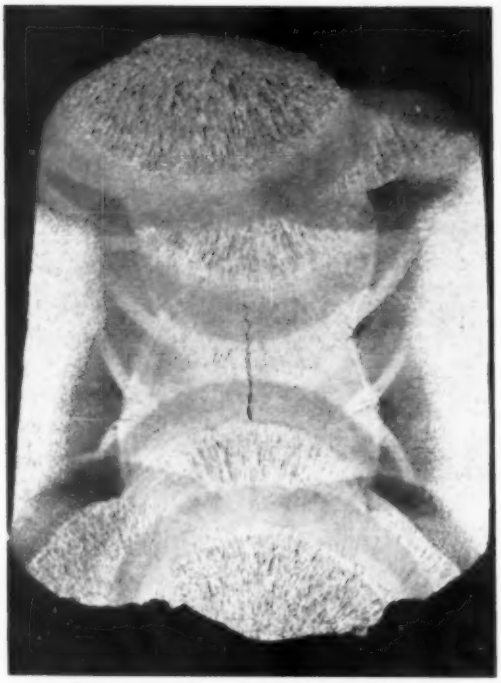

Fig. 4 – Center Crack in Welded Joint

the transition temperature of semikilled steel. Three different approaches have received special attention from the metallurgist:

1. Normalizing to reduce grain size, by heating rolled plates to about 1650° F., soaking until the plate has a uniform temperature, and then cooling in air. Normalizing lowers the transition temperature a little, but would require furnaces and associated facilities that are even more limited than those for producing killed steel. Accordingly, normalizing does not appear to represent a solution to the problem of emergency production of ship steel.

2. Special rolling techniques to reduce finishing temperatures. Research in the United States and production abroad have demonstrated that finer grain sizes and lower transition temperatures result from rolling or cooling practices that control the finishing temperatures. At the present time, these expedients do not appear to be compatible with high production rates. Low finishing temperatures require a delay at the finishing stands for cooling. Accordingly, until special equipment is available for controlled, rapid cooling between passes during final rolling, controlled rolling does not appear to represent a solution to the manufacturing problem.

3. Adjustment of composition. Many laboratory studies have shown that a reduction in carbon content lowers the transition temperature. To maintain strength in ship steel, a lower carbon must be accompanied by an increase in manganese, but manganese is limited to about 1.35% max. to avoid troubles with weldability. Present studies indicate that a semikilled grade containing a maximum of 0.20% carbon and from 1.00 to 1.35% manganese can be produced by conventional steelmaking practices with a reasonably good yield. Tests of such a steel indicate that it has a transition temperature low enough to be resistant to service failure in plates at least to 1½ in. thick. While some large tankers now under design require heavier plate, it is probable that any class of ships designed for large-scale emergency production would be small enough to use very little plate over 1½ in. thick.

Accordingly, an adjustment of composition does appear to represent a solution to the emergency production of large quantities of semikilled ship steel which will have the desired low transition temperature.

In summary, it appears that there should be no brittle fractures during normal service of ships built after 1947 incorporating A.B.S. Class A, B* and C steels. (This excludes, of course, accidental conditions where fracture is forced during collisions, explosions, or similar unusual circumstances beyond the control of the designer and ship builder.) Ships built during a future emergency will probably be as free from troublesome design details as Victory ships. It is likely, however, that there would be an initial period of construction during which the quality of welding would be low. Ships built during such a period would have a tendency to fail unless they incorporated steel with adequate notch toughness that could be produced during the emergency. A.B.S. Class A and B steels will be satisfactory for plates up to ½ in. and up to 1 in. thick, respectively. Plates over 1 in. – at least up to 1½ in. thick – should be satisfactory if made of a semikilled grade containing 0.20% max. carbon and from 1.00 to 1.35% manganese. Given a satisfactory manganese supply, it appears that this semikilled steel, resistant to service failure, could be produced during the emergency. Actions now being taken to assure the manganese supply during a possible emergency reinforce this conclusion.

*Particularly as made to specifications applicable after Jan. 31, 1956.

Fuel for the Atomic Engine

*By B. LUSTMAN**

The fuel in the Shippingport atomic power plant consists of long metallic elements of highly enriched uranium, arranged in a hollow square which encloses and is surrounded by a "blanket" of natural uranium oxide. This article describes the work necessary to prove the suitability of this material and the fabrication methods. (T11g, 17-57, R4; U)

OPERATION during 1958 of the first full-scale nuclear reactor generating electric power for civilian use in America has proved the soundness of the many decisions which had to be made in the design of this unprecedented plant, started up at Shippingport, Pa., in the preceding December. Many of these fundamental decisions involved choice of materials and fabrication processes. It will be my endeavor to describe a few of these in two articles, the first having to do with the fuel elements, and the second having to do with some important auxiliaries. It would be impossible within the limitations of space in *Metal Progress* to define all the problems which were faced (and circumvented if not overcome) in the pressurized water reactor project. This has been done at length in one of the books prepared by the U. S. Atomic Energy Commission for the Second Geneva "Atoms for Peace" Conference entitled "The Shippingport Pressurized Water Reactor". Only certain of the more unusual aspects of the material's technology can be described below.

Design Philosophy – Since the Shippingport plant is the first of an extended development program for power plants to use the heat from nuclear fission economically, and since about $100,000,000 or four fifths of the over-all costs are from governmental funds, the U. S. Atomic Energy Commission laid down broad directives for the project. Among these were that the fuel elements be suited to low-cost fabrication methods, that at least half of the heat come from natural uranium, that the core have a life of 3000 hr. or more at full power, and that the coolant be purified and pressurized natural water.

Based on these requirements, a study of the desirable pressures and temperatures and of the capabilities of the well-proven materials of construction led to the following compromise: Operating pressure to be 2000 psi.; water operating temperature 540° F.; lining of the reactor vessel and all piping carrying the pressurized water to be Type 304 stainless steel (nominal composition 19% Cr, 10% Ni, 0.08% max. C); cladding of the fuel elements to be the patented alloy known as Zircaloy-2 (1.5% Sn, 0.14% Fe, 0.10% Cr, 0.05% Ni) known from experience with naval reactors to be resistant to corrosion in the coolant and having a low neutron absorption coefficient.

Reactor Fuel – Given the above temperatures and pressures, the size of the reactor was limited by the then-existing capabilities of the pressure-vessel industry to be a 9-ft. cylinder, 31 ft. high with 8-in. walls. Figure 1 is a horizontal cross section of the lower third showing the arrangement of the core. The latter is an assemblage of two varieties, (*a*) "seed fuel" stacked around a hollow square, and (*b*) "blanket" clusters surrounding the square and filling its center.

Each of the 32 seed fuel assemblies is 5.5 in. square and 110 in. long. A cross section is shown in Fig. 2. The reactive metal is uranium highly enriched in the fissionable isotope U^{235} alloyed with 93.3% by weight of zirconium, and bonded by hot rolling to Zircaloy-2 by the well-known "pictureframe" method. The plates are 0.069 in. thick, and have 0.040 in. of uranium alloy "meat" in their center. The water channels are 0.069 in. wide. Individual plates are edge welded to form such assemblies by techniques frequently de-

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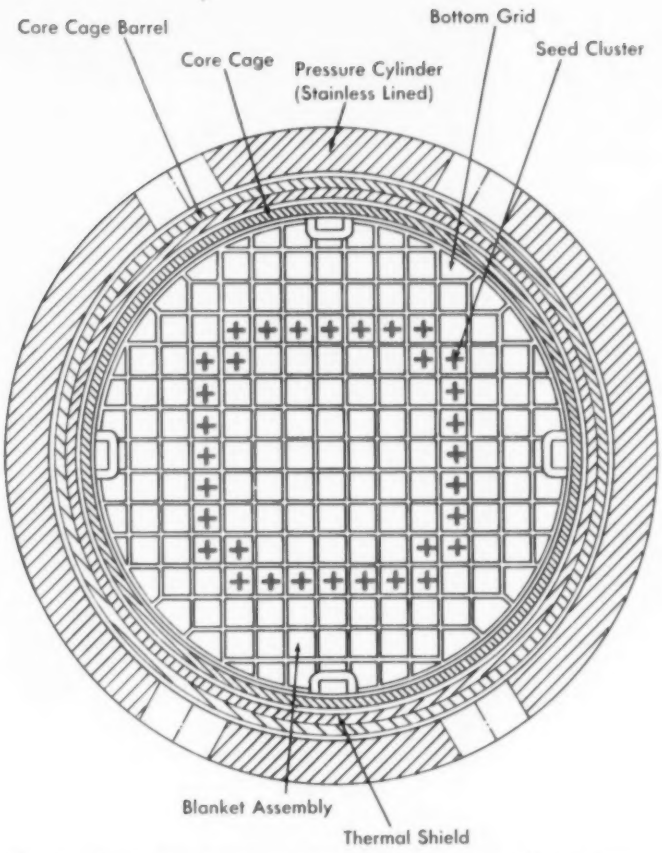


Fig. 1 — Horizontal Cross Section Through 9-Ft. Cylinder Comprising Reactor of Shippingport PWR. Open squares represent assemblies of natural uranium "blanket"; crosses represent hafnium control rods in center of "seed fuel", highly enriched in U^{235}

scribed in detail in the technical literature.

The blanket clusters are stacks of units shown in exploded view in Fig. 3. Each of the fuel rods is a seamless Zircaloy-2 tube, 0.413 in. O.D. with 0.025-in. wall, 10¼ in. long. Each tube contains 26 pellets, each about 0.357 in. in diameter and 0.357 in. long, and both ends are plugged with a cap, welded in. 120 of these tubes are then welded into tube sheets as indicated in Fig. 3, forming a bundle 5½ in. square by 10¼ in. high. Seven of these bundles, stacked end to end, match the length of the fertile portion of the seed clusters. Since Fig. 1 shows there are 45 such stacks in the center of the square and 68 around the periphery (a total of 113 in all) and there are seven clusters in each, this means that nearly 800 such clusters are required for the Shippingport PWR, and for them about 95,000 fuel rods were fabricated, holding 2,500,000 uranium pellets. Thus there is logic in the requirement that the fabrication must be done by mass-production methods.

The arrangement indicated in Fig. 1 permits the extensive use of natural uranium by concentrating the enriched metal in the seed elements, and requires a minimum of control rods and their associated mechanisms. It also has a negative temperature coefficient. The hollow square arrangement of seed assemblies does not produce enough neutrons from the enriched uranium it contains to sustain a chain reaction, even when they are slowed down by the moderating action of the water coolant, unless a considerable fraction are reflected back by the blankets.

During the operation, some of the neutron output of the fissionable U^{235} is also absorbed in the U^{238} in the blanket, producing plutonium which is also fissionable by neutrons of thermal energies. Since the quantity of plutonium builds up during the life of the core, the blanket material produces an increasing proportion of the over-all heat by "burning" the plutonium in place.

Blanket Fuel—The unique feature of the PWR from the standpoint of the materials is the use of UO_2 in Zircaloy tubing for the blanket fuel elements. The fuel, made from natural uranium, was to survive at least two seed lives, or a peak "burnup" of two out of every 100 uranium atoms in the blanket fuel. The only available experience in power reactors was limited to burnups in the range 0.1 to 0.3% of the uranium atoms and even this was by no means encouraging. In addition to long life, the plant should be capable of continuing to operate even if the cladding on several elements either developed defects during operation or contained undetected flaws resulting from fabrication.

These decisions imposed formidable obstacles to the use of the metallic uranium, since it is decidedly incompatible with water at any temperature, much less at the high temperatures of the PWR. However, we made a major effort to find a satisfactory uranium alloy and found

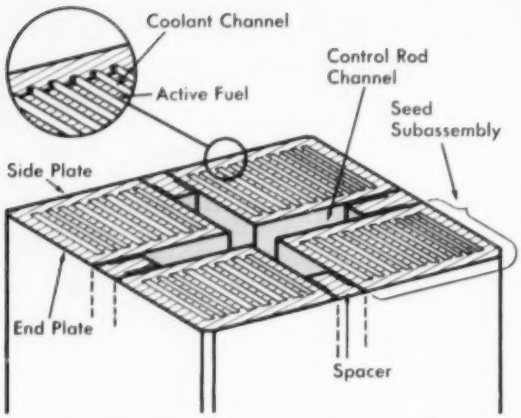


Fig. 2 – Top End of a Seed Fuel Cluster Which Consists of Four 2½-In. Square Assemblies, 72.4 In. Long. Cross at center is a channel for a hafnium control rod; each plate is clad with Zircaloy-2; dark center lines represent enriched uranium "meat", and white the channels for coolant

a class of alloys in which the body-centered cubic phase (stable in pure uranium above 1425° F.) was kinetically stabilized at reactor operating temperatures (600° F.) by additions of molybdenum or columbium or both. However, such additions with their high nuclear cross sections were unattractive additions to our "seed and blanket" arrangement. Furthermore, minor variables in fabrication caused large differences in their resistance to hot water corrosion. We therefore decided to devote our further efforts to a fuel inert to high-temperature water, namely uranium dioxide. Since previous experience with metal-clad UO_2 fuel elements had been confined to low-flux research reactors, the evaluation of uranium dioxide and its fabrication as a fuel element for the PWR was a major undertaking of the project.

This will now be described in some detail.

Out-of-Pile Evaluation – The hottest part of the stable fuel element (its center) should, for maximum reliability, be less than the melting point. Preliminary computations were based on the then available data on thermal conductivity of UO_2 and indicated that center temperatures in the PWR would be somewhat below the sintering temperatures of the pellets (3100 to 3200° F.). However, some new thermal conductivity measurements made at Armour Research Foundation gave values about 25% lower than those previously reported, and they indicated that the center temperatures might be in the neighborhood of the melting point of UO_2 – about 5000° F. (In-pile tests later revealed that the "effective" thermal conductivity of the fuel rod was even lower.)

Modulus-of-rupture data for temperatures up to 1850° F. indicated that solid UO_2 would probably break under stresses imposed by thermal gradients occurring during operation of the reactor. This expectation was confirmed not only by irradiation tests but also by out-of-pile tests of sample fuel elements rapidly cycled between 600 and 1500° F. However, the cracks appeared after the first few cycles (only about four to five cracked pieces per original UO_2 pellet) and even after thousands of such thermal cycles, no further cracks appeared. No trace of powdering or "ratcheting", such as would be induced by progressive disintegration, was noted. This warranted a design of the fuel rod which required no structural integrity of the fuel itself – the tubular container provided the necessary support for the fuel element.

Thermodynamic calculations showed that UO_2 should react to form higher oxides in pure water or water containing dissolved oxygen, but that the UO_2 structure would be retained if the element were exposed to water containing dissolved hydrogen. These calculations were confirmed by year-long tests in hydrogenated water at high temperature; no chemical or physical changes were discovered. Similar results were found in samples exposed to steam at temperatures up to the melting point of UO_2. In water containing an excess of oxygen, a nonadherent hydrated uranium oxide was formed. A further check on the validity of the thermodynamic calculations was obtained by finding that U_3O_8, exposed to hydrogenated water, was reduced to an oxide of the UO_2 structure. It was thus confirmed that under normal reactor operating conditions UO_2 is inert to the hydrogen-bearing coolant water in the PWR, and that during short periods of operation with accidentally oxygenated water, the rate of attack through any defect in the cladding is sufficiently slow to constitute no operational hazard.

Stability of the UO_2 powder and pellets during storage in air was also investigated. It was found that such reactions between UO_2 and air or oxygen occurred in two stages. In the first stage, oxygen diffuses interstitially in the UO_2 lattice to a composition of approximately U_3O_7. The second stage was characterized by surface nucleation and growth of a second phase, U_3O_8.

Similarly, the reaction between zirconium (Zircaloy-2) and UO_2 was measured at a series

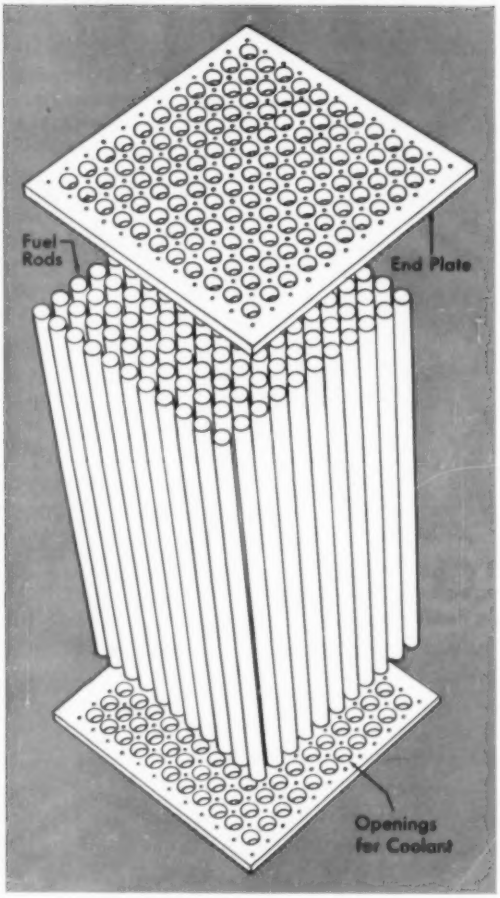


Fig. 3 – Exploded Isometric View of Blanket Assembly. Zircaloy-2 tubes containing UO_2 pellets are welded into tube sheets forming a unit 5½ in. square by 10¼ in. high

of temperatures. This reaction was accompanied by (*a*) the diffusion of oxygen into the zirconium matrix, (*b*) restricted formation of a metallic, high-uranium phase, and (*c*) diffusion of uranium into the zirconium matrix. However, this reaction was measurable only above 1100° F. and of appreciable magnitude only above 1300° F.; therefore, such reactions do not constitute a limitation to either the fabrication or the operation of the PWR fuel element.

UO_2 Powder – Since the UO_2 pellets were to be formed by powder metallurgical methods, we studied various types of oxide powder with respect to particle size, surface area, porosity, density (both real and apparent), and composition. We studied not only Mallinckrodt oxide powder (MCW) prepared by hydrogen reduction of UO_3, but also other powders made by oxidizing uranium or uranium hydride in high-pressure or low-pressure steam, by precipitation and subsequent pyrolysis of ammonium diuranate, and by hydrogen reduction of both U_3O_8 and UO_3. These varying techniques produced a wide range of particle sizes and powder characteristics, possessing marked variability in pressing and sintering behavior. Constancy in the inherent properties of the reference MCW powder resulted from ball milling, and fabrication variables were considerably reduced by high-pressure pressing. Consequently it was used for the 2,500,000 pellets for PWR Core 1.

The relations between porosity, density, and grain size are shown in Fig. 4, from which it appears that as densification proceeds (at constant sintering temperature and with increasing time) crystal growth and the distribution of residual porosity between that communicating with the surface of the compact (open porosity) and that entirely contained in the compact (closed porosity) follows a relatively complicated relationship. However, densities of 97.5% theoretical with small grain size were achieved by sintering in hydrogen at 3100° F.

During irradiation experiments, the very small residual porosity had a profound effect on the rate of release of the volatile fission products krypton and xenon from the matrix. At low sintering densities (Fig. 5A) the compacts contain large irregularly shaped pores apparently located on the grain boundaries, and also small regularly shaped pores usually observed in clusters inside the grains. As the density of the UO_2 compact approaches theoretical density (see Fig. 5B), the large pores develop regular symmetrical shapes and planes related to the crystallographic orientation of the grain in which they are located. At least some of them are bounded both by spherical surfaces and planes of a truncated octahedron.

The sintering of compacted UO_2 powder is strongly affected not only by the characteristics of the powder but also by the composition (excess oxygen beyond the stoichiometric ratio for UO_2) and the nature of the sintering atmospheres. Sintering temperatures required to attain greater densities than 95% of theoretical may be reduced from 3100 to 2550° F. by replacing the hydrogen atmosphere with a steam atmosphere, although the resulting compacts analyze $UO_{2.19}$. The ready diffusion of oxygen in the UO_2 crystalline lattice is in contrast with the fact that the uranium ions are relatively firmly fixed – self-diffusion is slow.

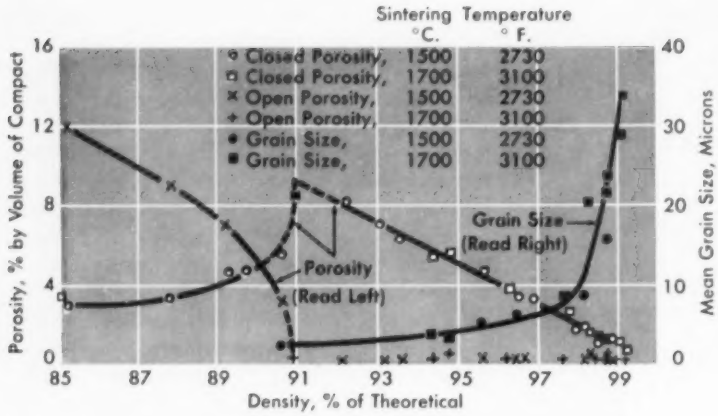


Fig. 4 – Porosity and Mean Grain Size of UO_2 Pellets Sintered at Various Temperatures. Mallinckrodt powder was wet ball milled, pressed to 65% density and sintered in hydrogen at either 2730 or 3100° F. "Closed Porosity" means openings entirely contained in the compact; "Open Porosity" means cavities open to the surface

In-Pile Evaluation – A major fraction of our developmental work was related to the in-pile validation of the use of high-density UO_2 compacts as a fuel material and was influenced primarily by the irradiation facilities available. One important class of tests was performed in high-temperature water loops both in the Chalk River NRX reactor in Canada and in the Materials Testing Reactor in Idaho*. Individual fuel elements, fabricated with planned variations of cladding-to-UO_2 clearance, or pellet density, were exposed at heat fluxes ranging from the average heat fluxes planned to almost double that of the hottest fuel elements in the Shippingport Core 1 blanket. Some samples had 5-mil holes drilled through the Zircaloy container to simulate reactor operation after a failure in the cladding of a fuel element.

Another important class of tests was that in which clad samples were cycled in and out of reactor flux to simulate the effects of start-ups, shutdowns, and power changes.

Finally was the proof testing of fuel element assemblies. A number of fuel elements were joined between tube sheets similar to Fig. 3, and were irradiated in high-temperature water loops at both Chalk River and Idaho to check the resistance to distortions imposed by unequal operation temperatures and hence varying thermal expansion.

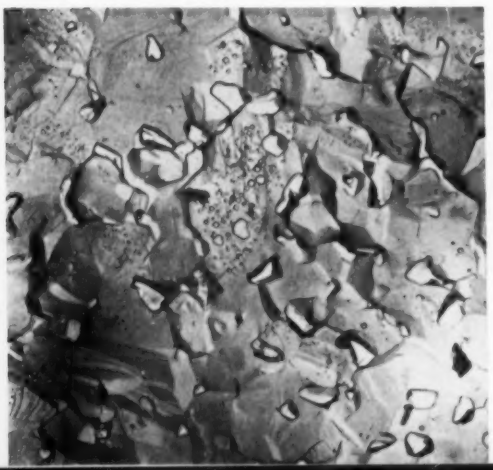
In all, a total of 360 fuel elements have either been irradiated and evaluated or are still undergoing irradiation in various reactors. Information has been obtained on the operation of such fuel elements at burnups as high as 25,000 megawatt-days per ton.

One of the most important results of this testing program has been to establish the thermal behavior of fuel elements as affected by operating heat flux, the effect of variable clearance between cladding and UO_2 pellets, and the nature of the atmosphere in this annular clearance. With a helium atmosphere and with 0.001 to 0.004-in. clearances, it was found that the

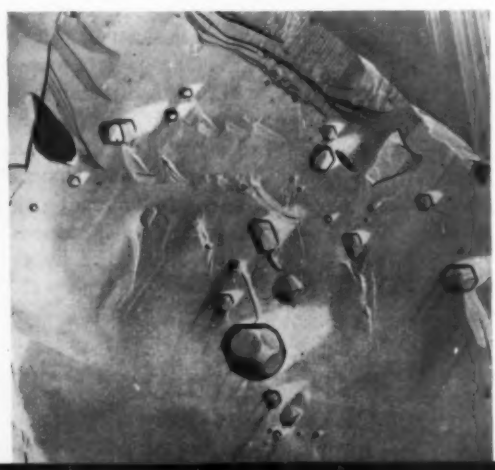
*The testing at Chalk River was a joint undertaking by the U.S. Atomic Energy Commission and Atomic Energy of Canada, Ltd. (AECL).

Fig. 5 – Electron Micrographs Showing Pores Revealed on Fractured Surfaces of Sintered UO_2 Compacts. 6000 ×

A – 90.9% Theoretical Density



B – 98.8% Theoretical Density



central spot in the pellet did not melt – that is, did not reach 5000° F. – at heat fluxes below 475,000 Btu. per hr. per sq.ft., 50% more than the designed operation of PWR. If clearance is raised to 0.005 to 0.008 in., the barrier to heat transfer by conduction is increased and the allowable heat flux decreases to about 400,000 Btu. If a fuel rod with small clearance operates with a defect in the cladding, thus having steam in the annulus instead of helium with its much better thermal conductivity, and converting the UO_2 to a higher oxidation state, the allowable heat fluxes before center melting occurs are reduced to about 400,000 Btu. per hr. per sq.ft., slightly greater than the maximum expected in PWR Core 1. These values should not change much with "burnup"; similarly, dilution of the helium with fission gases such as xenon and krypton has only a minor effect on the thermal behavior of the fuel element.

Despite the above observations, we actually found many instances where central melting (Fig. 6) or grain growth occurred at lower heat fluxes than anticipated – a matter yet to be satisfactorily explained.

Proof tests of blanket assemblies have shown no permanent distortions even when the heat fluxes between adjacent welded fuel rods have varied by as much as a factor of two. Other experiments simulated the most severe type of fuel element failure, which would result in blocking the cooling water channels, to find whether there was any probability of failure progressing from a broken element to an adjacent good one. In no instance was any ill effect observed upon an element resulting from malfunctioning of an adjacent one. Therefore, the likelihood of encountering progressive failure in PWR Core 1 is considered highly remote.

Metallic uranium has been widely used as an atomic fuel. Plastic straining – and even rupturing – of such fuel element cladding has been noted from the formation of additional atoms upon fissioning and the accumulation of volatile fission products, particularly the noble gases xenon and krypton, within the metal structure. No trace of such changes has been found in the UO_2 pellets and their containers, indicating that, as least for burnups of 25,000 megawatt-days per ton, fission products can be accommodated within the crystalline architecture without marked structural changes. The volatile fission product gases also appear to diffuse out from the UO_2 fuel. In this connection, one should remember that there is plenty of surface from which the outwardly diffusing gas can escape. Measurement of sintered compacts has shown that real surface areas even in compacts sintered to 93% of theoretical density may be over 100 times as much as the exterior area.

The release of volatile fission products may have several consequences:

1. By diluting the helium gas placed in the annular space between pellets and Zircaloy container, the conductivity of the fuel element can be diminished enough to detract from the correct thermal performance.

2. Such fission products, if they escape, will contaminate the coolant and thus reduce plant accessibility.

3. At sufficiently high burnup levels, enough pressure may be generated within the fuel element to rupture the cladding.

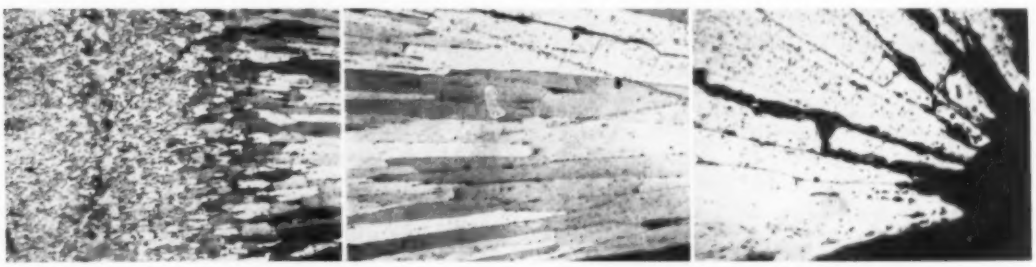


Fig. 6 – Melting in Center of UO_2 Pellets Resulted in Columnar Crystals. Photo series not composite. 50 ×

However, both experiment and analysis show that such effects do not limit the fuel element performance for burnups of the order of five times the maximum anticipated for PWR Core 1.

Cycling experiments, both in-pile and out-of-pile, have revealed no progressive fracture of fuel pellets during operation. Such fracture as is observed results primarily from the thermal stresses; hence no degradation of the structure of the compact occurs, and cracking is limited

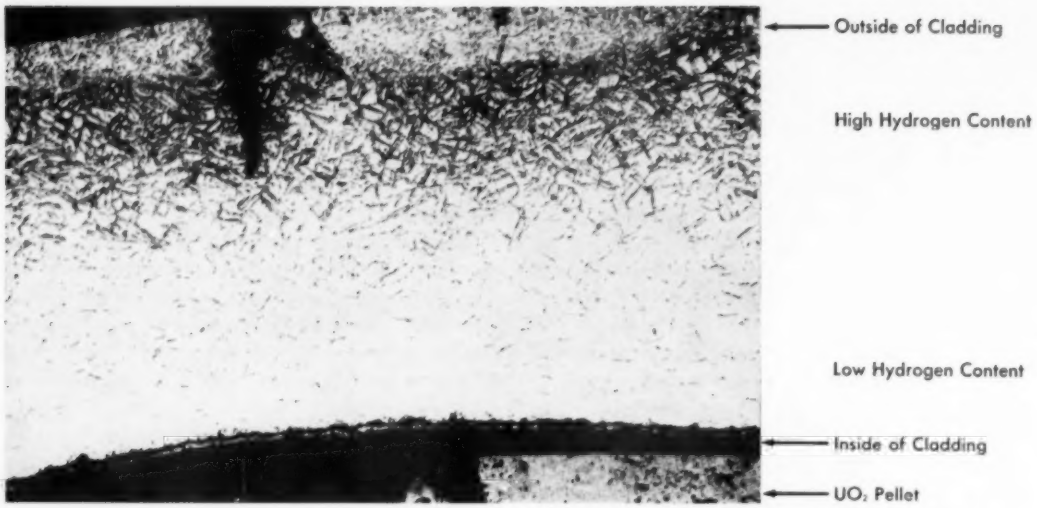


Fig. 7 – Water Intentionally Admitted Into the Zircaloy Cladding Forms Hydrogen During Irradiation, Which Diffuses Through the Cladding Producing a Brittle Surface Susceptible to Cracking Due to Thermal Stresses. 90 ×

to that which can be reproduced in out-of-pile thermal shock tests. As a consequence, "ratcheting" of fuel and its consequent deterioration have not been observed.

Another possible failure mechanism that was postulated was "waterlogging", in which water would penetrate a crack or hole in the Zircaloy-2 tube and soak into the pores of the UO_2 compacts. If this occurs during a reactor shutdown, expansion of this water into steam when operation restarts would create excessive interior pressures. While indications of such waterlogging were encountered in tests on low-density compacts or rods containing unsintered powder, none of the tests on high-density compacts have been disturbing. We conclude that such waterlogging failures are highly unlikely on high-density, sintered compacts.

Examination of the microstructure of compacts irradiated to burnups up to 25,000 megawatt-days per ton has revealed no microstructural changes other than those anticipated from the temperature of operation. Thus, grain growth is noted at operational temperatures higher than 3100° F., the sintering temperature of the compacts. However, no evidence of microstructural change, grain growth, pore formation or disappearance, or precipitation of second phases has been noted at lower temperatures of operation. X-ray diffraction studies of irradiated UO_2 have revealed only a slight line broadening; in contrast, irradiation of U_3O_8 powder resulted in almost complete elimination of diffraction peaks. Thus, UO_2 appears capable of withstanding irradiation at high temperature with minimum structural change.

A number of UO_2 fuel rods containing intentional built-in defects were operated in high-temperature water loops at very high heat fluxes. Defects or cracks in the cladding (Zircaloy tubing) formed at different locations, and at each of these failures there was a high local concentration of hydrogen in the zirconium. The hydrogen migrated to the outside of the cladding by a thermal diffusion process, resulting in a marked local decrease in ductility and resistance to thermal stresses. A typical example is shown in Fig. 7, where the hydride phase has segregated at the relatively cooler outer surface of the cladding. This sample was irradiated three months at high heat-flux ratings in high-temperature water. The troublesome hydrogen comes from water which leaked into the fuel rod through the intentional defects; experiments show that sufficient hydrogen is not absorbed by the zirconium cladding during fabrication or operation at normal operating temperatures to cause failure by this mechanism, and sound rods have not failed from this mechanism.

Conclusion – The experimental program on PWR Core 1 blanket fuel rods thus served to validate the use of an oxide fuel, establish its performance capabilities, determine suitable conditions for fabrication and design, and set a basis for interpreting the performance of Core 1 blanket rods during operation of the Shippingport reactor.

Automatic Controls for Protective Atmospheres

*By WILLIAM C. DIMAN**

Automatic proportioning valves, dew point indicators, flash back arresters, blow-offs, flame controls, temperature regulators, pressure regulators, alarms, flow meters and system interlocks are assembled according to the needs for protecting workmen, equipment and material in process. (W28q, X7, X13f)

THE DAY of "peephole" control of atmosphere generators is passed! Of course, there are still many units in service which operate under purely visual controls, but the trend is definitely toward greater instrumentation. Heat treatment of the more complex alloys requires rigid control of the protective atmosphere to safeguard working conditions and prevent unnecessary, costly shutdowns.

The purpose of this article is to indicate a few of the types of control equipment which improve the operation of atmosphere generators. Most equipment manufacturers will gladly recommend the best controls for a heat treating installation, and some offer actual laboratory demonstrations to prove the advantages of various control combinations. As atmosphere equipment becomes more complex, the caliber of the operating personnel must increase. Situations that demand immediate and accurate corrective measures can and will arise – sometimes so rapidly that even the most proficient attendant will be unable to visualize the full scope of the problem immediately and make the necessary corrections.

Proper controls are therefore no longer an optional item; they are essential.

Types – Atmospheres for protecting or improving surfaces during heat treatment may be classified into three general categories – inert, oxidizing and reducing. Although inert and oxidizing atmospheres often warrant regulation, this article will be limited to the control of *reducing* atmospheres.

Equipment for this purpose may again be divided into three general categories, depending on the source of the reducing atmosphere – exothermic generators, endothermic generators and ammonia dissociators. Since this article concerns atmosphere *producing* equipment, reference to bottled hydrogen, hydrogen formed by electrolysis, iron contact, catalytic or other processes, will be referred to only as "hydrogen source".

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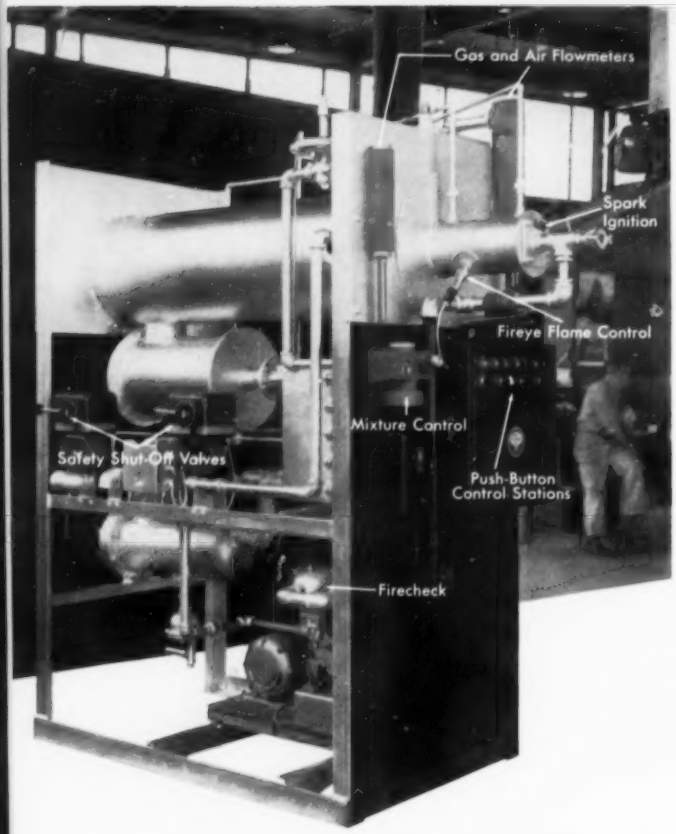


Fig. 1 — Exothermic Generator With Controls for Automatic Operation and Safety

Exothermic Generators

The product of an exothermic generator, such as shown in Fig. 1, is the result of cracking a predetermined mixture of hydrocarbon gas and air over a heated catalyst. The percentage of hydrogen that may be obtained is dependent on the ratio of the gas to air in the mixture. However, since the temperature of the catalyst bed is maintained by the products of combustion, the reaction is limited.

A typical exothermic reducing atmosphere commonly used for bright annealing, normalizing, brazing, and sintering of ferrous and nonferrous metals would be produced by a 6 to 1 ratio of air to natural gas. The percentage of hydrogen in the resulting atmosphere (approximately 18%) would be considered only mildly inflammable and explosive. Therefore, automatic controls are primarily for start-up, and contribute to safety and ease of operation.

Figure 1 shows an example of push-button operated safety controls. To start the generator, the operator presses in sequence each button of the push-button control station and makes the necessary adjustments to the combustion through the mixture control. The electrical circuits are arranged so the generator will not function if buttons are not pressed in their proper sequence, left to right. An electronic flame-sensing eye ("Fireye Flame Control") will shut down the equipment in the event of loss of combustion.

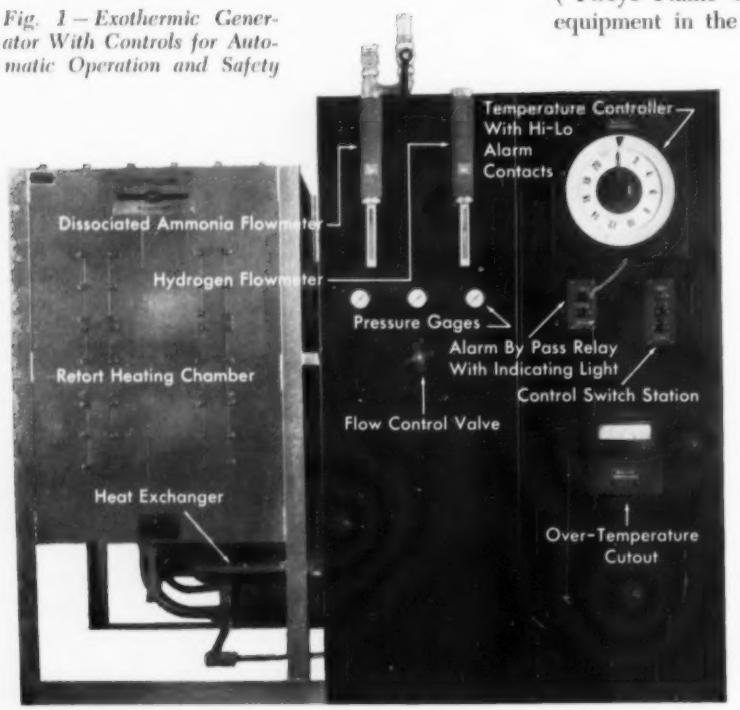


Fig. 2 — Control Board Showing Operational and Safety Controls for the Ammonia Dissociator

Another safeguard is a solenoid safety shut-off valve in the generator outlet, which prevents the admission of atmosphere into a furnace unless the furnace temperature is above the ignition point of hydrogen. This safety shut-off valve is energized through contacts in the furnace control instrument.

The exothermic generator also has these controls for ease of operation and safety:

1. A solenoid safety shut-off valve in the inlet gas supply which will close in the event of loss of combustion, loss of power, loss of gas pressure, or a flash-back.
2. A firecheck or flash-back arrester in the gas-air line between the combustion controls and the combustion chamber.
3. A pressure relief valve in the atmosphere vent line that will automatically open if an internal pressure builds up for any reason between generator and furnace.
4. Automatic controls of water supply to cooling jackets or condenser bottles.
5. Gas-air flowmeters and special sight ports located in the immediate vicinity of the push-button control station and mixture controls, so the operator can visually check the flame and follow changes in gas-air flow as adjustments are made to combustion controls.

Endothermic Generators

The endothermic generator differs from the exothermic in this respect: The temperature of the catalyst bed is not dependent on the ratio of the gas-air mixture flowing through it, but is maintained by placing the catalyst-filled retort in a heating chamber. By maintaining a uniform temperature in the catalyst bed, it is possible to use a gas-air mixture that will produce an atmosphere containing 30 to 40% hydrogen. Since this is quite inflammable and, under certain conditions, extremely explosive, endothermic atmospheres should be handled with the same respect as dissociated ammonia and hydrogen.

In place of the flame-sensing eye, special "Hi-Lo" electrical contacts are incorporated into the electronic temperature control instrument to sound an alarm if either over-temperature or under-temperature conditions should develop in the heating chamber. A time clock is usually supplied so the generator can be heated before the work shift begins. With the generator at temperature, the operator presses a starting button which energizes the combustion controller. He then adjusts a vernier control for the proper gas-air ratio, and the proper atmosphere almost immediately starts issuing from the retort.

If the furnace that is being supplied with atmosphere is a standard box type, and its temperature is well above the ignition point of hydrogen, the prepared atmosphere may be admitted directly into the furnace. If, on the other hand, the furnace is equipped with internal cooling chambers or enclosed quenching sections or any other area where the temperature could be below the ignition point of hydrogen, it must first be purged with an inert gas before admitting the endothermic atmosphere. Proper start-up and shutdown procedures are generally set up by a field engineer or representative of the equipment manufacturer.

An endothermic atmosphere, in general, is used to maintain or improve the surface of the material being treated, and there are various other controls available for measuring and controlling the carbon potential or dew point of the atmosphere so it may have the desired effect on the parts being processed. Conditions vary with the alloy, the temperature and the surface carbon content.

Because this article is primarily concerned with automation, it will not attempt to cover all of the available systems but will touch very briefly on one type. An endothermic generator may be furnished with a complete dew point control system that will operate as follows: A sample of the endothermic atmosphere is continually removed from the heat treating furnace and passed over a moisture-sensing cell. The H_2O in the gas sample is measured and the measurement converted to electrical energy and amplified enough to operate a proportioning valve that increases or decreases the amount of enriching gas (propane) to the furnace as required. This means that the operator need only set the furnace temperature control and the dew point control and wait until both instruments indicate that stabilized conditions have been reached within the furnace; then treatment can begin. If the heat treating cycle is short and the furnace door must be opened frequently, a time-delay relay may be used to shut off the dew point sampling line while the furnace door is open and for a predetermined time afterward. This will keep wet gas out of the dew point measuring system and prevent overcorrecting the dew point by excessive enriching gas.

Ammonia Dissociators

The dissociating of ammonia into its components, 75% hydrogen and 25% nitrogen by

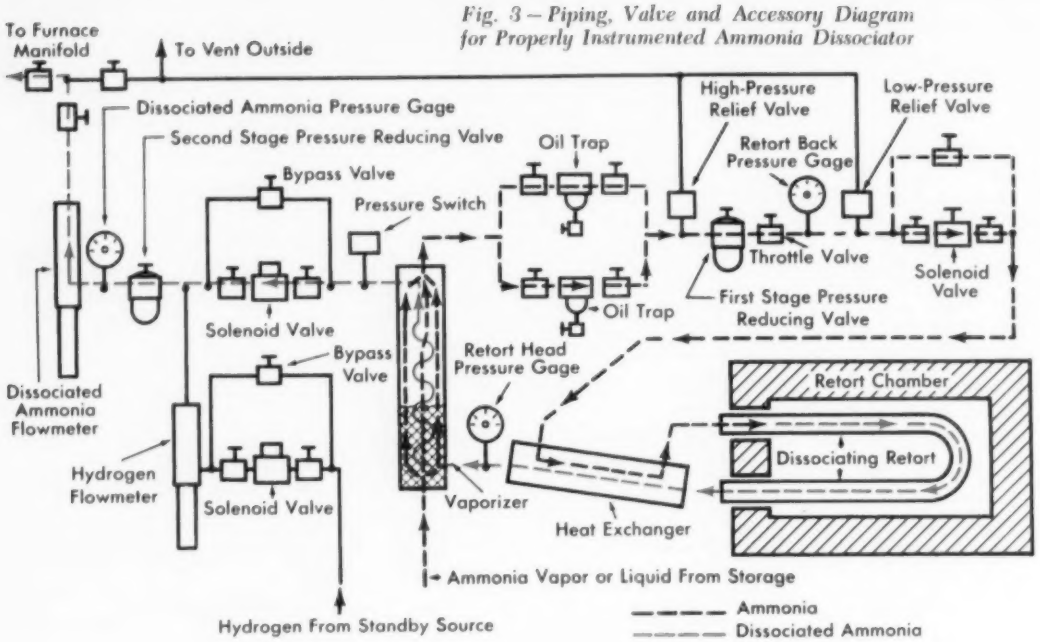


Fig. 3 – Piping, Valve and Accessory Diagram for Properly Instrumented Ammonia Dissociator

volume, is done by passing NH_3 vapor over a heated catalyst. So, in essence, the ammonia dissociator consists of a heated retort for cracking the vapor. All additional equipment may be considered broadly as accessories to facilitate operation and insure safety. The ammonia dissociator in Fig. 2 is hidden behind the panels mounting most of these accessories. Their functions – designed to relieve the operator of as much responsibility as possible – are outlined in their proper sequence in Fig. 3 and in the following paragraph.

A good grade of ammonia enters the vaporizer as a liquid or cold gas and exists as fairly hot vapor which passes through an oil trap and continues to the first-stage reducing valve where the pressure is reduced to about 20 psi. gage. (Note the parallel oil trap loop to permit cleaning without shutting down the dissociator.) The vapor then passes through the throttle valve, solenoid valve and outer portion of the heat exchanger to raise its temperature still higher. Going thence to the dissociating retort, it is cracked into its component gases, hydrogen and nitrogen. From the dissociating retort these gases pass through the inner partition of the heat exchanger and the vaporizer. The cooled gases then go through the second-stage pressure reducing valve, and from here through the output flowmeter and on to the manifold or furnace.

A high-pressure relief valve is installed between the ammonia vaporizer and the first-stage reducing valve to vent the system automatically if pressure builds up for any cause. A similar low-pressure relief valve is installed on the downstream side of the reducing valve to vent that section of the ammonia system if pressure builds up.

Three solenoid valves are included at appropriate spots to shut off automatically the supply of dissociated ammonia and to supply hydrogen gas if there is a pressure drop in the ammonia supply line or if over-temperature or under-temperature conditions develop in the retort.

If any out-of-control conditions develop, an alarm sounds. The operator can then press an alarm bypass relay button located on the instrument panel, which shuts off the bell and lights a red signal which remains on until the trouble is found and remedied. If there is a total loss of power to the dissociator, the solenoid in the hydrogen supply line will open and a hydrogen atmosphere will continue to flow into the receiving furnace. (This emergency standby gas can be either nitrogen or hydrogen, depending on the type and treatment of work being processed.)

Purge Systems

Purge systems are used with many types of protective atmospheres. The basic elements are

shown in simplified schematic form in Fig. 4 – a combination flow diagram and photograph of a "Hump" furnace. Actual systems are available in many types and modifications too numerous to detail in this article, and are usually designed by the heat treating equipment manufacturer to meet specific requirements.

Here is how the purge system shown in Fig. 4 operates:

1. The operator opens the supply valve and the purging gas (nitrogen, in this illustration) flows through the nitrogen flowmeter and through the normally open (N.O.) nitrogen solenoid valves into the receiving furnace. The pressure gage will indicate pressure and the pressure switch will have closed. The needle valve will then be adjusted to give the correct flow at the existing pressure.

2. The system is allowed to purge for the necessary time, generally determined and set by the field engineer when the equipment is installed. The purging cycle will vary with the type and size of the furnace.

When the furnace is purged and safe to accept hydrogen or the dissociated ammonia atmosphere, the selector switch may be closed. The alarm will sound, but the safety shut-off valve (which will now operate) can be immediately opened and the prescribed amount of atmosphere will flow into the furnace through the adjusted needle valve in the supply line for hydrogen or dissociated ammonia.

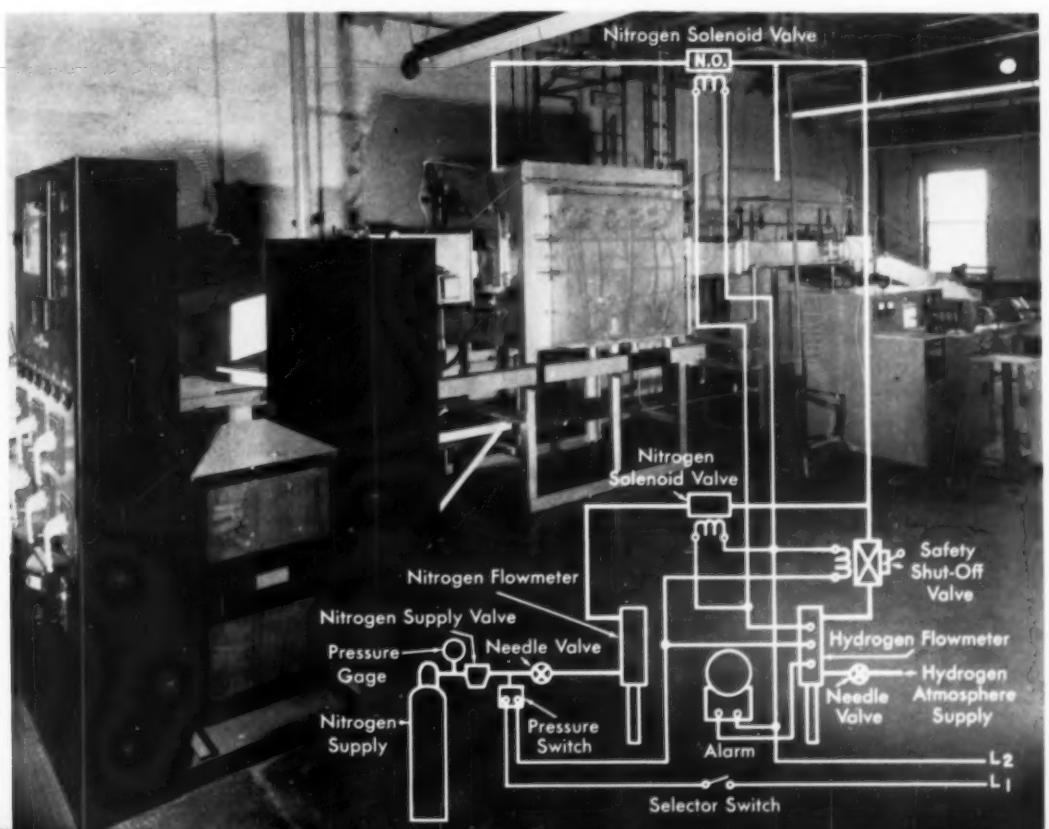
4. When atmosphere starts entering the furnace, the hydrogen flowmeter will trip out the alarm circuit and transfer the energizing current to the nitrogen solenoid valves to cut off the flow of nitrogen. The furnace is now ready for operation, and the system is alert for any interruption of atmosphere or power.

5. To shut off the atmosphere, the selector switch is opened. This closes the safety shut-off valve and opens the nitrogen solenoid valves. When the furnace has been completely purged, the nitrogen supply is shut off.

Conclusion

It is hoped that the above all-too-brief account of the means which are available, in the form of automatic equipment and signals, properly interlocked, will give some idea of the means whereby working conditions around atmosphere generators and atmosphere furnaces can be safeguarded and unnecessary expenditures from costly shutdowns reduced. It is obvious that the details for any particular furnace installation must be carefully engineered to meet the specific conditions required by the operating metallurgist.

Fig. 4 – Purge System Diagrammed on Photograph of a "Hump" Furnace



Control of Magnetic Particle Testing

*By J. W. SCHWEIKERT**

Suspensions can be tested in 2 min. with a hand-operated centrifuge; the settling test outlined by most specifications lasts 30 to 60 min. This new method, easily managed by machine operators, makes it simple to keep magnetic particle baths within specification limits. (S13j)

HERE's an interesting question if you do magnetic particle inspection. What would you do if a customer challenged your present testing system – and you were subsequently proved to be inspecting with suspension out of specification limits? Well, those who wish to avoid such a predicament might consider testing with a centrifuge. It offers a fast, accurate method for rating magnetic particle suspensions. Furthermore, military inspectors have permitted its use, and it is being written into government specifications.

Standard Methods

Why was this system developed? Frankly, it stemmed from the continuing emphasis on more stringent quality controls. These needs naturally extend to control of inspection techniques, as well as control of the part itself. However, a number of complications combine to make present control methods rather inefficient. For one thing, standard equipment seldom maintains a uniform mix for an extended period. Furthermore, military and industry specifications which must be followed are not only vague about the frequency with which suspensions should be checked, but also spell out slow and costly settling techniques for testing. Consequently, inspection performed while waiting for suspension readings is not reliable. If a suspension is found out of control, parts must either be re-inspected or accepted at a risk.

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Present Requirements

Detecting cracks, flaws, seams, nonmetallic inclusions and other imperfections by magnetic particle inspection is a routine operation in many plants. The wet method is most commonly used. As set up by specifications, and augmented by company procedures, standard practice calls for suspensions to be checked periodically. These tests usually involve a delay of 30 to 60 min. before the operator is certain that the concentration is within limits. Vague military specifications add to the difficulty. Quotations given below will show what we mean.

AMS 2640 F

3.1.1 Suspension – Suitable means shall be provided for agitating suspensions. The paste suspension shall consist of magnetic substance of adequate concentrations in the liquid vehicle to produce clear indications of imperfections with the magnetizing procedure, type of paste, and examining method used.

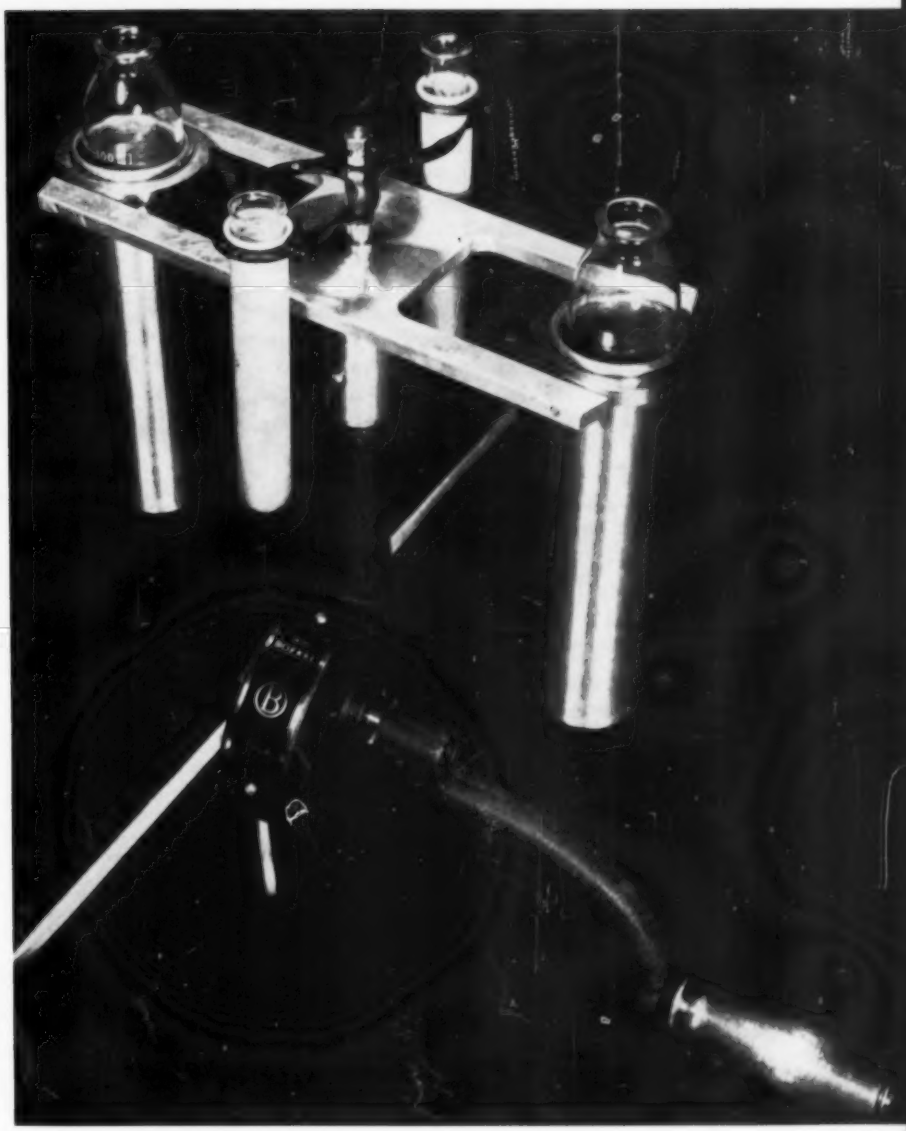

Fig. 1 – Centrifuge for Testing Suspensions. When the crank is turned 40 times in a minute, the 100-ml. bottles whirl at 600 rpm. (Note: The special head which holds two test tubes was added for another experiment)

3.1.4 Test of Suspension – Suspensions shall be tested as often as necessary to maintain proper control; the following is a satisfactory testing procedure.

3.1.4.1 After not less than 30 min. of continuous pump circulation of the suspension, fill a 100-ml. cylinder . . . to the mark with the suspension directly from the hose . . . demagnetize, and let stand for 30 min., or until the solid matter is apparently all down. Decant the clear liquid . . . refill the tubes . . . using . . . solvent . . . shake well, and let stand for 1 hr. to settle out a second time. Read the volume . . .

3.1.4.1.1 Other methods of test which produce equivalent results may be substituted for the above method. (Note: This paragraph provided us with a loophole for our centrifuge method.)

MIL-I-6868 A

8.2.2 Alternate Method of Test

1. Fill an A.S.T.M. 100-ml. graduated centrifuge tube (pear-shaped) to the mark with suspension directly from the hose (or other device used for pouring it over the piece in making a test), or from an immersion tank after the suspension has been thoroughly agitated. Demag-

netize the suspension if this is considered necessary and let it stand for 30 min. to precipitate, or until the solid matter all settled.

2. Read the height of volume of the precipitate in the graduate. The results should be as follows: (*a*) for nonfluorescent magnetic particles: 1.7 to 2.4 ml.; and (*b*) for fluorescent magnetic particles: 0.3 to 1.3 ml.

Centrifuge Method

Faced periodically (or "as often as necessary", according to specifications) with these lengthy tests, we decided to shorten the time by using a centrifuge. The simplest and most economical one available was a hand-operated unit accommodating two 100-ml. tapered bottles. It is illustrated in Fig. 1. The spindle ratio of 16:1 provided about 600 rpm. when the crank was turned 38 to 40 rpm. Although there was no measurable difference in precipitation rate when input varied from 35 to 45 rpm., all data were obtained at a uniform 40 turns to eliminate any speed variable.

Suspension Concentration

All suspensions which were obtained from production machines were blended to get concentrations ranging across and overlapping limits of acceptance stated by Specifications AMS 2640 F or MIL-I-6868 A. A comparison was made between a three-week-old mix (used daily) and new solution, freshly prepared, and no measurable difference was noted. These tests were made with suspensions of red visible paste, oil base; red visible paste, water base; and fluorescent magnetic paste, water base.

Correlation Test Method

For each sample, the concentration ranged across upper and lower limits of the specified suspension. The sample was placed in a 100-ml. centrifuge bottle, and (after thorough shaking to assure uniformity) allowed to stand undisturbed for 30 min. to permit settling. A reading was made and recorded. The bottle was then shaken thoroughly and placed in the centrifuge. After the crank was turned 40 times and brought to a quick stop, a reading was made and recorded. The two points for the same concentration were then plotted. The concentration in each bottle (two samples are handled at a time) was changed by decanting some of the liquid, and pouring some concentrate from one bottle to another. This increased one concentration and decreased the other. Settling and centrifuge tests were then repeated. Eighteen or more readings eventually established both the slope of the curve and the range of correlation.

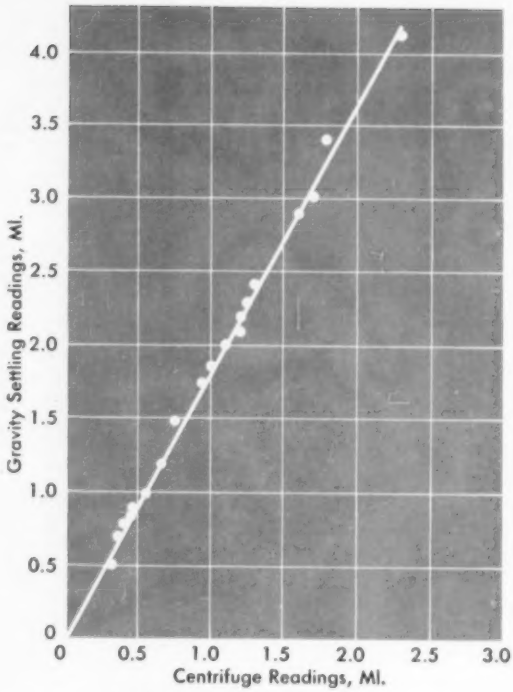

Fig. 2 – Correlation of Gravity and Centrifuge Tests. This chart rates red paste No. 9 in an oil base; other tests were carried out with red paste No. 29 in a water base and Magna-Glo No. 24 in water. Excellent correlation was observed in all tests

Experimental Results

An example of the experimental results is shown in Fig. 2. For a given suspension, the graph indicates a straight-line correlation between the gravity settling rate and the centrifuge settling rate. Obviously, the method is accurate. It is also rapid; measurement is completed in less than 2 min. Repeatability by operators was excellent.

Another advantage – almost psychological in nature – became evident. Operators were willing to take readings more frequently – they now had a laboratory "gadget" to operate and apparently felt more important. Requests to take readings when work was finished were met with enthusiasm, and we learned a good deal about each machine.

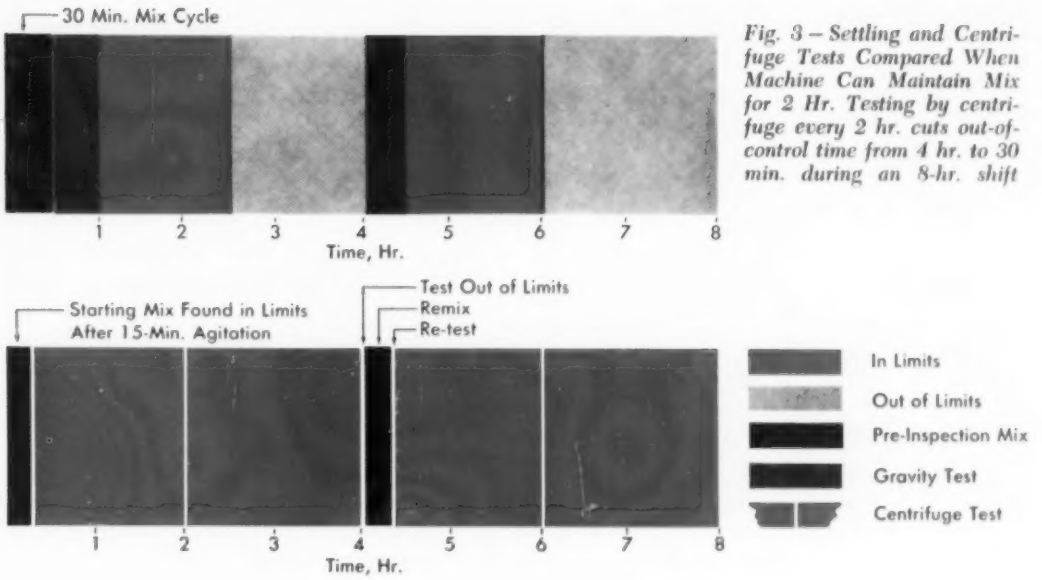

Fig. 3 – Settling and Centrifuge Tests Compared When Machine Can Maintain Mix for 2 Hr. Testing by centrifuge every 2 hr. cuts out-of-control time from 4 hr. to 30 min. during an 8-hr. shift

Maintaining control is not easy. Even when pumps and agitators worked continuously, suspension remained stable for only a few hours. Pumps clogged, power failed, concentration lessened due to use; these all contributed to instability. The centrifuge immediately showed the amount and nature of contamination washed from parts inspected, or due to poor housekeeping. Even when a given machine was reworked to provide enough agitation for a perfect mix, the concentration still had to be determined periodically, due to "carry-out". We found it less expensive to buy and use a centrifuge than to rework machines to improve agitation. Figure 3 illustrates typical daily cycles for machines being tested by both gravity and centrifuge methods. With gravity, the suspension is tested twice a day, and is out of control for 4 hr., while with the centrifuge, testing is done four times a day, and the out-of-control period is reduced to 30 min.

Recommendations

With this information available, we can make a few suggestions. First, it seems logical to determine how long each machine can maintain a given suspension, and establish this period as the maximum time between suspension readings. Suspension checks should be at the beginning and end of each cycle, readings being permanently recorded at each machine. Centrifuges can be installed and operators trained to use them. As a final step, mixing capability of the machine can be improved.

Check Your Own Machines

Those of you who have to work with magnetic particle equipment and government inspectors might be interested in the following check list. Try it on your own machines.

1. How long will your machines hold suspension concentration within specification limits?
2. How frequently do you check concentration?
   a. Is the cycle time shorter than No. 1 above?
   b. What records do you have of the various checks performed?
   c. Do you take concentration readings after the cycle and before extra agitation?
3. Is your agitating equipment automatic and adequate?
   a. If not, does your planning sheet call for extra manual stirring at intervals?
4. How long do you require for gravity settling before reading?
   a. What does operator do during this period? Idle time? Inspect parts?
   b. If check shows concentration out of limits, do you re-inspect parts or assume risk?
5. Are you subject to customer inspection?

Your subsequent action depends, of course, on your answers to these questions. If you find periodic testing necessary, we suggest that the centrifuge offers an inexpensive, simple and rapid method for it.

Surface Fatigue of Carbo-Nitrided Steel

*By G. W. POWELL**
M. B. BEVER†
and C. F. FLOE†

Observations supplementing previous work by these authors indicate that carbo-nitrided cases must be thick enough to withstand service-induced stresses. Otherwise, the mechanical properties of the core, which are lower, will determine the fatigue life. (Q7, J28m; ST)

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†Professors, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge.
The authors wish to thank the Ammonia Div., Armour & Co., Chicago, and Prof. E. Buckingham for their support and assistance.

Book Review

Study of Materials Based on Their Structures

*Reviewed by JACK WASHBURN**

THE SCIENCE OF ENGINEERING MATERIALS, edited by J. E. Goldman, John Wiley & Sons, Inc., New York, 1957. 528 p. $12.00.

OUR ARTICLE in *Metal Progress* (March 1958) reported on an investigation of surface fatigue of carbo-nitrided and carburized steel. In that investigation, tests were carried out by rotating two rolls in peripheral contact under various radial compressive loads. One was a standard roll of 1.1% carbon steel, hardened and tempered to Rockwell C-62 to 64, the other a test roll of case hardened steel. The tests showed that the fatigue life of a carbo-nitrided case was raised by at least a factor of 20 when the case depth was increased from 0.030 to 0.042 in. Also, a greater fatigue life resulted from a refrigeration treatment; this improvement could be attributed to the reduction of retained austenite in the carbo-nitrided cases.

This report concerns structural observations on a series of carbo-nitrided specimens which were not discussed in detail before. Rolls were machined from A.I.S.I. 1020 steel, carbo-nitrided at the fairly low temperature of 1350° F. for 7 hr., quenched in oil and stress-relieved for 1½ hr. at 325° F. The case depth was about 0.011 in. Surface fatigue performance of these rolls was inferior to that of rolls case hardened at higher temperatures. (*Continued overleaf*)

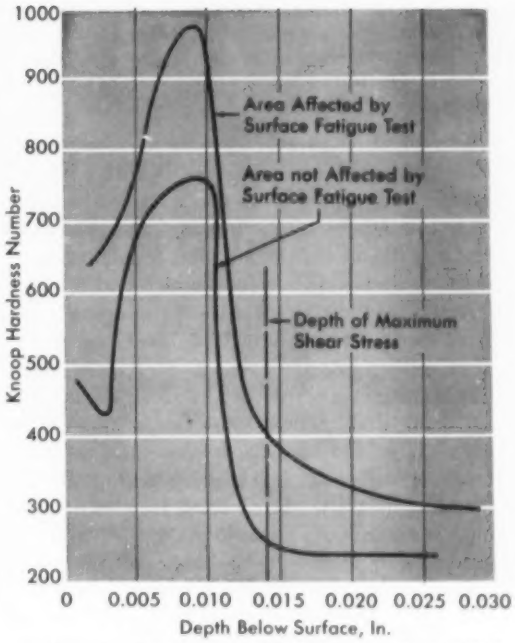

Fig. 1 – Hardness Variations in Carbo-nitrided Case. The upper curve is for the area contacted by the test roll, and the lower curve is for an adjacent area not affected by the test

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FROM the very beginning man's ability to use materials has played a key role in the development of civilization. The procedures and processes for making the thousands of different metallic and nonmetallic materials in use today have, for the most part, been learned by the trial and error method. Since about 4000 B.C., when the first metals were reduced from their ores in a campfire, knowledge of materials increased but slowly. But over the past 50 years – and particularly within the past 20 – rate of accumulation of technical knowledge has increased dramatically. Hundreds of useful and completely new materials, such as special magnetic materials and semiconducting materials, have come into use.

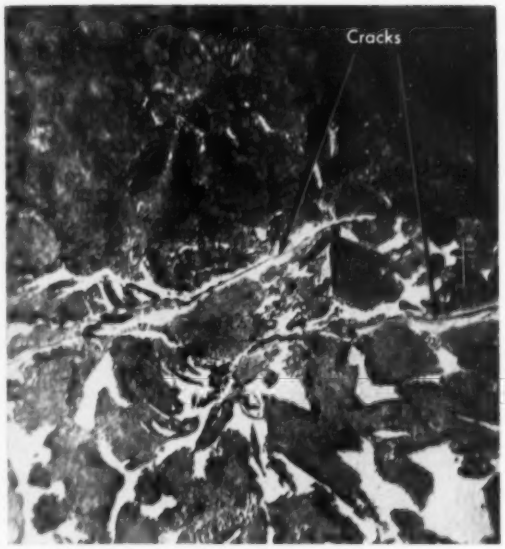
Why have we suddenly been able to transform experimental materials into useful products in such a short time? This book supplies the answer. The tools and techniques now available allow us to look at the *structure* of materials – the structure of the atom, the geometry of atomic arrangement in homogeneous materials, the microstructure in multiphase materials. We now know that properties depend on structure. We understand why steel is hard after quenching from a red heat and we know why some quenched aluminum-copper alloys harden with age. This knowledge of why materials behave as they do has been a powerful aid in the development of new materials.

"The Science of Engineering Materials", edited by J. E. Goldman, presents an excellent and authoritative account, by a number of outstanding specialists, of our understanding of the relationship between structure and properties of materials. It should be particularly valuable to engineers who are faced with complex service applications requiring a fundamental approach, since a thorough understanding of the behavior of materials makes selection much easier.

The authors have clearly related material properties to structure on an atomic and microscopic scale. Because the subjects include large segments of solid-state physics, metallurgy and chemistry, the presentations are generally simpli-

*Associate Professor of Metallurgy, University of California, Berkeley, Calif.

Fig. 2 — Cracks in Ferrite at Case-Core Junction. This photograph and Fig. 1 indicate that core properties determine fatigue life if the case is too thin. Magnification 500 ×; Nital etch



Microhardness traverses were made across the case and are shown graphically in Fig. 1. One sample was chosen from the surface which had been in contact with the standard role during the test and the other from an immediately adjoining area on the beveled surface, which had not been affected by the test. These two samples, therefore, represented the surface layer before and after testing. As indicated in Fig. 1, the calculated maximum stress occurred at a depth of 0.014 in., that is, below the lower limit of the case. Case and core hardnesses increased as a result of deformation occurring during the surface fatigue tests. In addition to work hardening, stress-induced transformation of retained austenite to martensite in the case must have helped to increase the hardness.

Figure 2 illustrates the transition zone between case and core of the specimen which yielded the hardness data. Cracks can be seen traversing the soft ferrite immediately below the case. The formation of such cracks — they are generally parallel to the roll surface — ultimately produced large pits which caused failure by destructive pitting.

These observations clearly demonstrate the need for adequate case depth to obtain maximum resistance to surface fatigue. Otherwise, fatigue life is determined mainly by the core properties rather than those of the case.

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fied and qualitative. The book emphasizes the universal validity of certain basic structure-property relationships for all types of materials. It should be particularly valuable to specialists who wish to gain at least a minimum understanding of important phenomena outside of their own field.

The book is not entirely suitable as a text. For advanced courses in science of materials, the treatment is too broad and not complete enough in any one area. For a beginning course, broad coverage is desirable but this book lacks continuity partly due to the multiplicity of authors. The level of presentation varies from chapter to chapter and in general presumes greater knowledge of mathematics, chemistry and physics than can be expected of students taking a first course in materials. It should be of great value to instructors of elementary material courses, since it contains and brings together in one volume so much useful experimental and theoretical information.

As we develop a fuller understanding of such mechanisms as plastic deformation, fracture, electrical conductivity, and magnetic phenomena, the traditional boundaries which call for the separate study of metals, ceramics and plastics will tend to disappear. This process has already begun at many leading universities where the same basic courses in thermodynamics, heat and mass transfer, crystal chemistry, atomic structure mechanics and dynamics, are given jointly to the metallurgist, ceramicist and chemist. This broad point of view in the study of materials tends to accelerate research progress. Metallurgists have gained new insight in the plastic flow of metals by studying slip in ionic crystals. Ceramic engineers are only now relating mechanical properties of ceramic bodies to microstructure — a well-established metallurgical technique. The laws of creep that apply to metals can be used with little modification for ceramic materials and plastics. "The Science of Engineering Materials" follows this trend.

Titanium Alloys Today

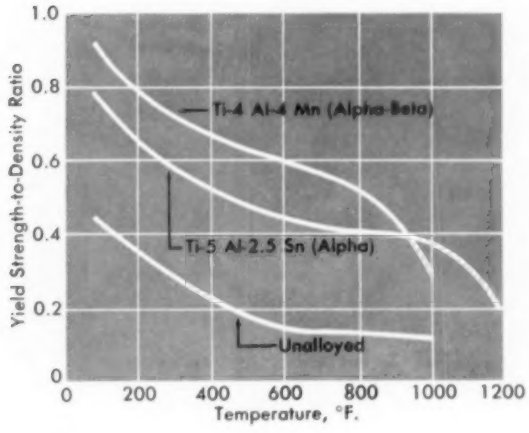
—How Commerical Alloys Compare

*By PAUL D. FROST**

Divided into alpha, alpha-beta, and beta types, commercial titanium alloys have widely varying properties. Alpha alloys have high strength and good oxidation resistance at elevated temperatures, but cannot be heat treated readily. Alpha-beta and beta alloys respond to heat treatment and are more formable than alpha alloys. Research and development programs will broaden applications. (Q-general, 17-57; Ti-b)

LAST MONTH, we discussed the metallurgical behavior of titanium alloys. In general, these alloys fall into three classes depending on the phase (or phases) present at room temperature. Because aluminum is the only metallic alpha stabilizer, it is the main component in all commercial alpha alloys; beta stabilizers, such as chromium, manganese and iron, are constituents of alpha-beta and beta alloys. The phase (or phases) present largely determine properties of the alloys. The Data Sheet in *Metal Progress* last month summarized properties of commercial and semicommercial titanium alloys.

Fig. 1 — Yield Strength-to-Density Ratio of Titanium Alloys. Alpha-beta alloys are stronger to about 900° F.; above this temperature, alpha alloys are stronger. (Courtesy Crucible Steel Co. of America)



Alpha Alloys

Generally speaking, alpha alloys have highest strength and best oxidation resistance at high temperatures (600 to 1100° F.) of all titanium alloys; other important properties are good weldability and low density. However, without a beta phase, these alloys have lower strength at room and moderately elevated temperatures. Furthermore, they respond only slightly, if at all, to heat treatment.

Figure 1 shows the relationship between yield strength-to-density ratio and temperature for an alpha alloy (Ti-5 Al-2.5 Sn), an alpha-beta alloy (Ti-4 Al-4 Mn), and unalloyed titanium. All are annealed. The superior strength of the alpha-beta alloy over the alpha alloy persists up to about 900° F.

One of the first commercial alpha compositions was the alloy, Ti-5 Al-2.5 Sn. It has been used extensively where weldability and strength are both required. However, in the last year several

*Chief, Light Metals Division, Battelle Memorial Institute, Columbus, Ohio. This is the second of two articles on status of titanium alloys. The first appeared last month and dealt with metallurgical principles of titanium alloy systems.

new alpha alloys have appeared. Two of these, Ti-8 Al-1 Mo-1 V and Ti-8 Al-2 Cb-1 Ta, have comparable properties. Stronger than Ti-5 Al-2.5 Sn, both alloys contain higher aluminum contents as well as having beta-stabilizing elements. The latter additions also help prevent embrittlement attributed to intermediate phases in binary titanium alloys containing 8% or more aluminum. Tensile data for Ti-8 Al-1 Mo-1 V are shown in Fig. 2.

Figure 3 shows the stress-rupture properties of Ti-8 Al-1 Mo-1 V after three different annealing treatments. Strength increases as temperatures rise; this is attributed to the amount of acicular (basketweave) alpha. Similarly, hot working in the beta field and finishing in the alpha-beta field improve creep strength. This also aids impact strength at some sacrifice in tensile ductility.

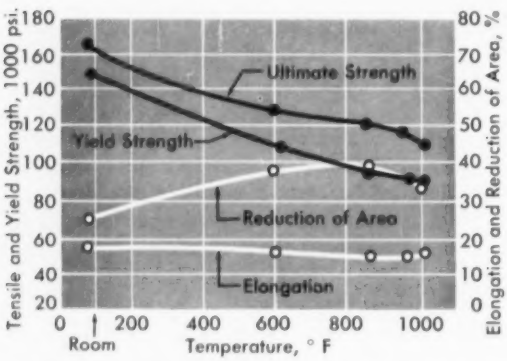


Fig. 2 — Tensile Properties of Ti-8 Al-1 Mo-1 V. Alloy was rolled in beta field, annealed 1 hr. at 1650° F., air cooled, and reannealed 24 hr. at 1100° F. (Courtesy E. Bohanek and H. D. Kessler, Titanium Metals Corp. of America)

Mallory-Sharon MST 881 (Ti-8 Al-8 Zr-1 Ta+ Cb) is a recent addition to the all-alpha high-temperature alloys. Now available as bar stock, the alloy is suitable for service up to 1100° F. for extended periods. For short periods, it is useful up to 1600° F. The tensile strength (for slow and fast loading rates) is shown as a function of temperature in Fig. 4.

Applications for Alpha Alloys

At present all-alpha alloys are not being used at the high temperatures to which their useful range extends. Rather, they are chiefly employed where weldability and moderate strength, at or below 1000° F., are required.

A typical aircraft application for Ti-5 Al-2.5 Sn is the angle shown in Fig. 5. It is formed at 1100

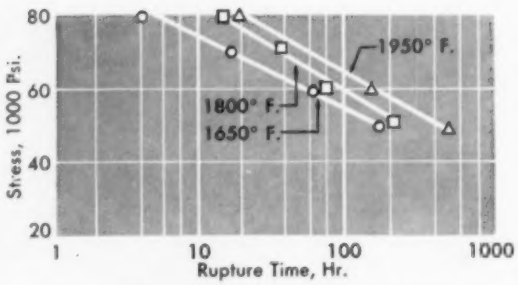


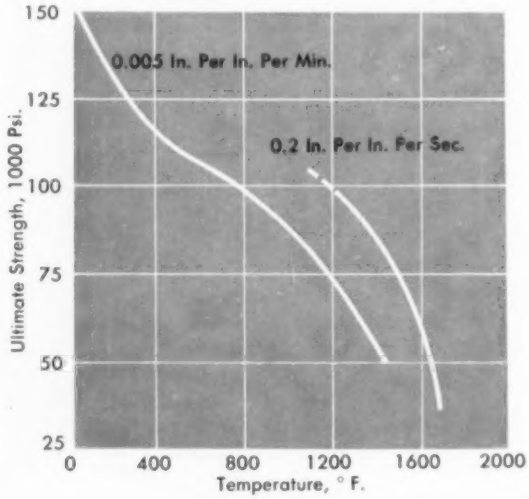
Fig. 3 — Effect of Temperature of Solution Annealing on Stress-to-Rupture Properties of Ti-8 Al-1 Mo-1 V. After annealing at 1100° F. for 24 hr., the tests were performed at 1000° F. (Courtesy E. Bohanek and H. D. Kessler, Titanium Metals Corp. of America)

to 1150° F. by stretch-wrapping. (Forming at 1000° F. resulted in the springback pictured). To minimize the Bauschinger effect (loss of compression yield strength due to residual stresses induced by cold stretching), these and similar parts are held on the heated die for a predetermined time.

Undoubtedly, the alpha alloys will eventually be required to withstand stresses and temperatures closer to the limits of their capabilities.

Tests are in progress at Douglas Aircraft Co. to evaluate Ti-5 Al-2.5 Sn for the tail pipe of the A 4 D Navy Midget Bomber (see Fig. 6). Now constructed mainly of Multimet N 155, this 22-in. diameter pipe is 145.5 in. long; it is required

Fig. 4 — Effect of Temperature and Strain Rate on Ultimate Strength of Ti-8 Al-8 Zr-1 Ta + Cb (MST 881). This alloy is suited for service up to 1100° F. (Courtesy Mallory-Sharon Metals Corp.)



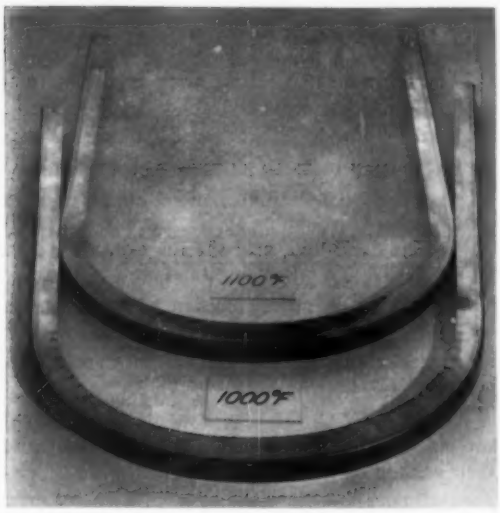


Fig. 5 – Titanium Alloy Angles Formed by Stretch-Wrapping Around Heated Dies. Note springback in part formed at 1000° F. (Courtesy Convair Div., General Dynamics Corp.)

to operate up to 1050° F. When the pipe was formed from Ti-5 Al-2.5 Sn sheet (0.025 in. thick), springback caused some difficulty. Lap joint resistance welds also failed in the forming rolls. Since forming was conducted at room temperature, this was not surprising. Spot and seam welding behavior was excellent. Despite these troubles, the tail pipe performed satisfactorily in preliminary engine tests and another pipe is being constructed for flight tests. If the titanium tail pipe is adopted, weight savings will amount to about 30 lb.

Alpha-Beta Alloys

These vary widely in composition and general characteristics. At one end of the alloy range are deep hardening alloys, such as Ti-2 Fe-2 Cr-2 Mo and Ti-4 Al-4 Mn, which provide high strength at room and moderately elevated temperatures. At the other end are the lean alpha-beta compositions. Typical alloys here are Ti-6 Al-4 V and Ti-7 Al-4 Mo; these are shallow hardening, but their comparatively high aluminum content gives them high strength and improved elevated-temperature properties.

As a class, alpha-beta alloys have higher strength and respond better to heat treatment. They are more formable than alpha alloys. However, these alloys are not weldable, and they lose tensile ductility when heated or hot worked above the beta transus temperature.

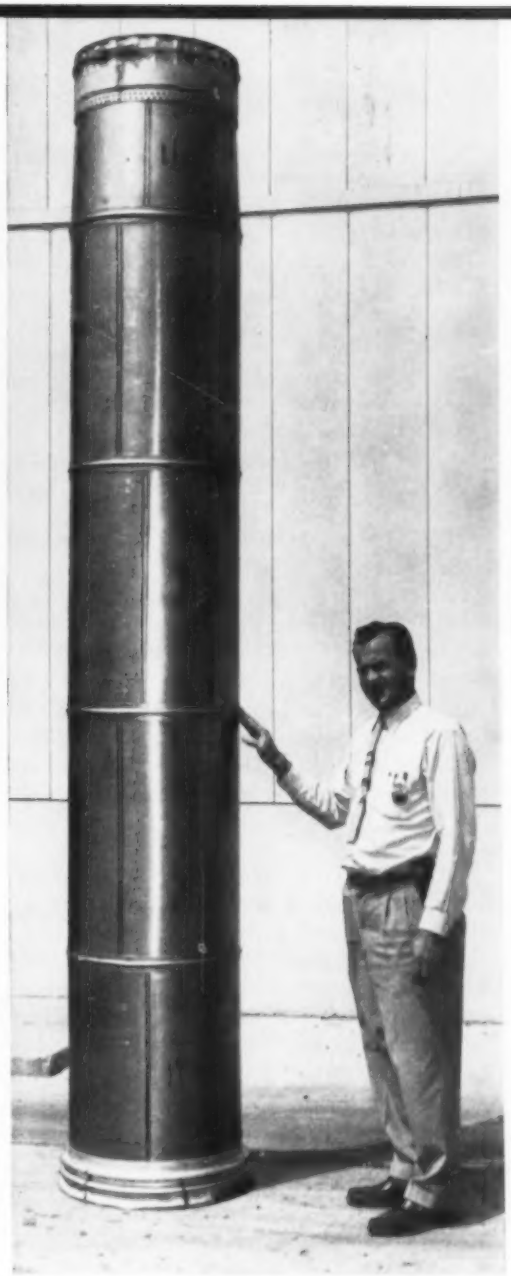


Fig. 6 – Titanium Alloy Tail Pipe for Navy A4D Midget Bomber. This pipe is now being evaluated in engine tests. (Courtesy Douglas Aircraft Co.)

Two of the oldest alloys are Ti-8 Mn and Ti-4 Al-4 Mn. The former, although it develops high strength with heat treatment, has almost always been used in the annealed condition. The Ti-4 Al-4 Mn alloy, a forging material, has excellent hardenability; because it contains aluminum, it also retains good strength up to temperatures of 800 to 900° F.

Actually, the following alloys should be interchangeable for most forging and bar stock applications except those requiring prolonged

exposure above a temperature of about 600° F:

Ti-2 Fe-2 Cr-2 Mo
Ti-4 Al-4 Mn
Ti-6 Al-4 V
Ti-5 Al-2.75 Cr-1.25 Fe
Ti-5 Al-1.5 Fe-1.4 Cr-1.2 Mo
Ti-7 Al-4 Mo
Ti-3 Al-5 Cr

Where maximum stability at elevated temperatures is required, alloys with more aluminum are better. If the maximum depth of hardening is needed, alloys with maximum content of beta-stabilizing elements are more suitable.

Data comparing tensile strength at elevated temperature of three different alpha-beta types, all made by the same producer, are shown (along with data for unalloyed material) in Fig. 7. This is an interesting comparison because the three alloys represent three alpha-beta types: (1) Ti-6 Al-4 V—lean alpha-beta; (2) Ti-5 Al-1.4 Cr-1.2 Mo—moderately beta-stabilized; (3) Ti-2 Fe-2 Cr-2 Mo—highly beta-stabilized. Several observations can be made from data in Fig. 7:

1. Ti-2 Fe-2 Cr-2 Mo (code 3) responds most to heat treatment.

2. Ti-5 Al-1.4 Cr-1.2 Mo (code 2) is the strongest of the three alloys in the annealed condition; it also responds well to heat treatment.

3. Ti-6 Al-4 V (code 1) and Ti-5 Al-1.4 Cr-1.2 Mo (code 2) retain about the same amount of their strengths up to about 700° F.; above this, Ti-6 Al-4 V is more stable. Ti-2 Fe-2 Cr-2 Mo (code 3) is less stable.

4. The improvement in strength produced by heat treatment lasts up to 1000° F. in two alloys and up to about 900° F. in Ti-2 Fe-2 Cr-2 Mo.

Although data are not included here, impact strength of Ti-6 Al-4 V is superior (to that of the other two) because it contains more alpha.

Alpha-Beta Alloy Applications

High-strength alpha-beta alloys are finding many diversified uses, particularly for forgings, fasteners and sheet applications. To extend their usefulness, a great deal of research is being done on extrusion, but so far, surface quality and tolerances are inadequate. Only limited quantities of extrusions for special applications are being used.

An interesting new application for Ti-6 Al-4 V is the rotor of the General Electric turbonator (Fig. 8), which combines a turbine with an electric generator. Operating at 24,000 rpm., turbine and rotor are on the same shaft. Retaining rings and top sticks are made from titanium.

Beta Alloys

The only metastable beta alloy in commercial production today is Ti-3 Al-13 V-11 Cr. It can be readily formed (1 to 3 t bend radius) at room and slightly higher temperatures, and it has better weldability than alpha-beta alloys. As for heat treatment, it can be solution treated, formed in the soft condition, and then age hardened to high strength. The alloy has somewhat higher density than most other commercial alloys, and is not thermally stable above 700° F. Tensile data for heat treated sheet and impact data are shown in Fig. 9.

The alloy promises versatility for both sheet and bar stock applications. For one thing, its ability to be cold worked makes it the first high-strength titanium alloy that can be used for cold headed bolts.

The Sheet Rolling Program, initiated by the Department of Defense, is a government-industry

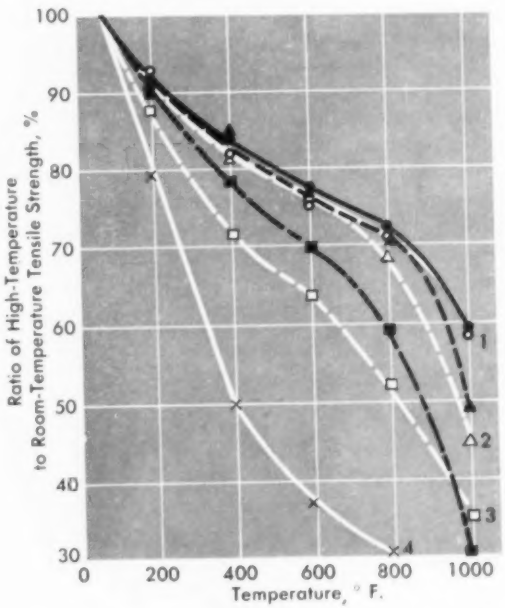


Fig. 7 — Comparison of Tensile Strength of Pure Titanium With Three Alloys in the Mill-Annealed (Black Curves) and Heat Treated (White Curves) Conditions. The following table gives pertinent data:

Room Temperature Tensile Strength

Code	Alloy	Mill Annealed	Heat Treated
1	Ti-6 Al-4 V	145,000 psi.	165,000 psi.
2	Ti-5 Al-1.4 Cr-1.2 Mo	165,000	180,000
3	Ti-2 Fe-2 Cr-2 Mo	135,000	175,000
4	Ti (99.2% pure)	67,000	—

cooperative effort to advance production of improved titanium alloys commercially. This program has three phases:

1. To develop best techniques for producing uniform, heat treatable sheet alloys having certrain minimum strength and forming properties.
2. To develop design data for alloys to be used in military equipment.
3. To evaluate fabricability and properties of the alloys and establish shop experience in aircraft plants for potential users.

Today, three titanium producers, at least six aircraft companies, and several research laboratories are participating in the program. Alloys currently evaluated include Ti-6 Al-4 V, Ti-4 Al-3 Mo-1 V, Ti-2.5 Al-16 V and, recently added, Ti-3 Al-13 V-11 Cr. The Ti-6 Al-4 V and Ti-3 Al-13 V-11 Cr alloys have already been discussed. The Ti-4 Al-3 Mo-1 V and Ti-2.5 Al-16 V alloys are alpha-betas which can develop high strength through heat treatment.

In the months since the first contracts were let by the Navy and the Air Force on Phase I, methods have been developed for melting alloys and producing sheet of reproducible properties. A major problem—heat treating full-size sheets—has been largely overcome. Phases 2 and 3 are now under way.

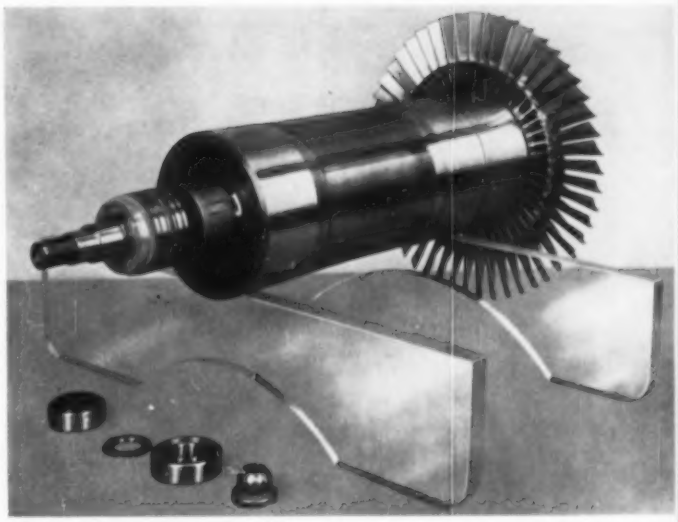


Fig. 8 — General Electric "Turbonator". Alloy Ti-6 Al-4 V is used for retaining rings and top sticks. (Courtesy Titanium Metals Corp. of America)

Active eutectoid alloys are alpha and alpha-beta alloys in which nickel or copper stabilizes the beta phase. Though these two elements form eutectoids in titanium in the same manner as does iron or chromium, their compounds precipi-

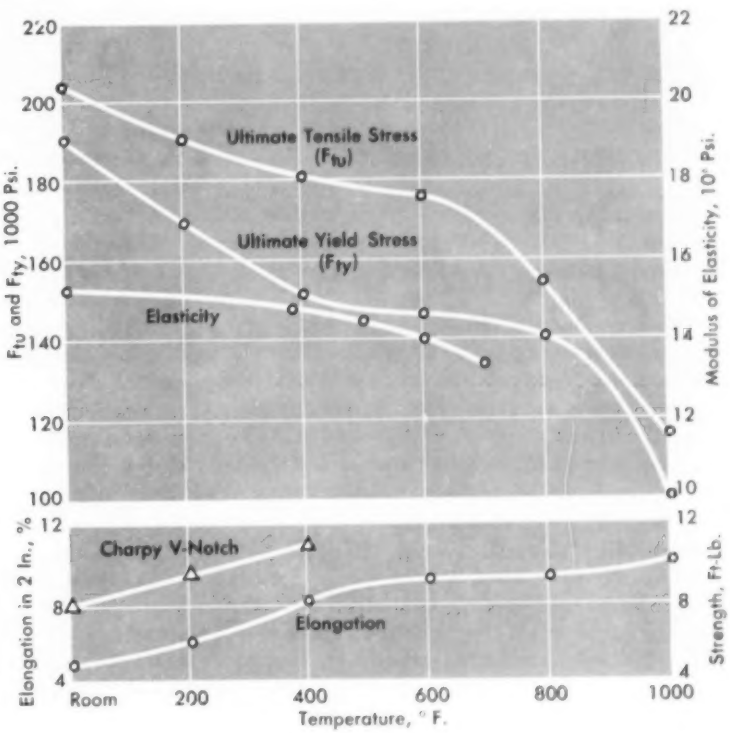


Fig. 9 — Some Properties of Ti-3 Al-13 V-11 Cr — the Only Commercial Beta Alloy. Sheet which was solution treated and aged was tested. (Courtesy Crucible Steel Co. of America)

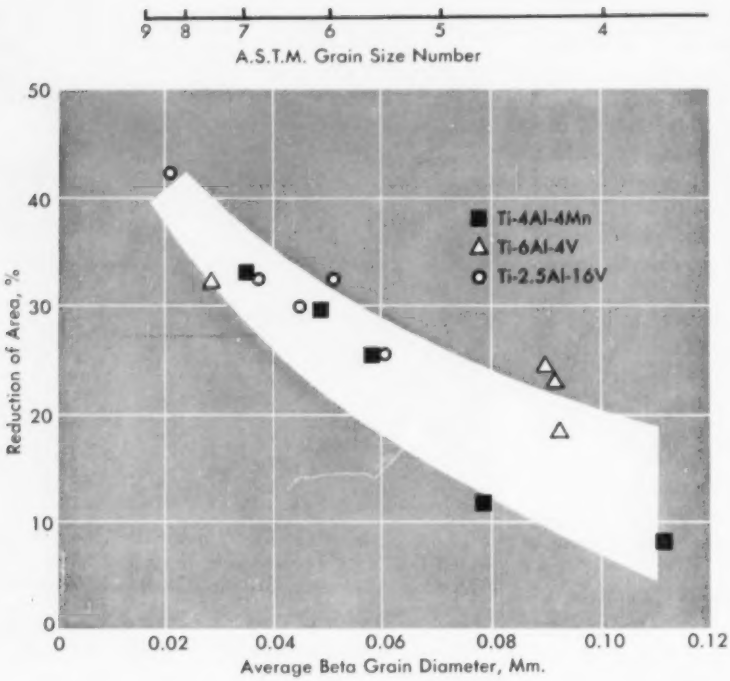


Fig. 10 – Effect of Beta Grain Size on Tensile Ductility of Three Alpha-Beta Alloys

tate much more rapidly. Consequently, alloys with these elements are usually called active eutectoid alloys. Through heat treatment, these can be strengthened considerably by virtue of the following reaction:

$$\beta \rightarrow \alpha + \text{compound}$$

Although alloys of this type are not commercial, they may have future significance. One example has the nominal composition Ti-7 Al-6 Cu-6 Zr. Some of its properties include:

Tensile strength (room temperature)	165,500 psi.
Tensile strength (1200° F.)	108,900
Rupture life (1000° F., 50,000 psi. stress)	695 hr.

These elevated-temperature properties are outstanding.

However, alloys of this type are subject to embrittlement under certain conditions of stress and temperature. Research is in progress to ascertain whether this is associated with the precipitation of an intermediate phase of titanium and aluminum, or is caused by the copper-rich eutectoid.

Cause of Beta Embrittlement

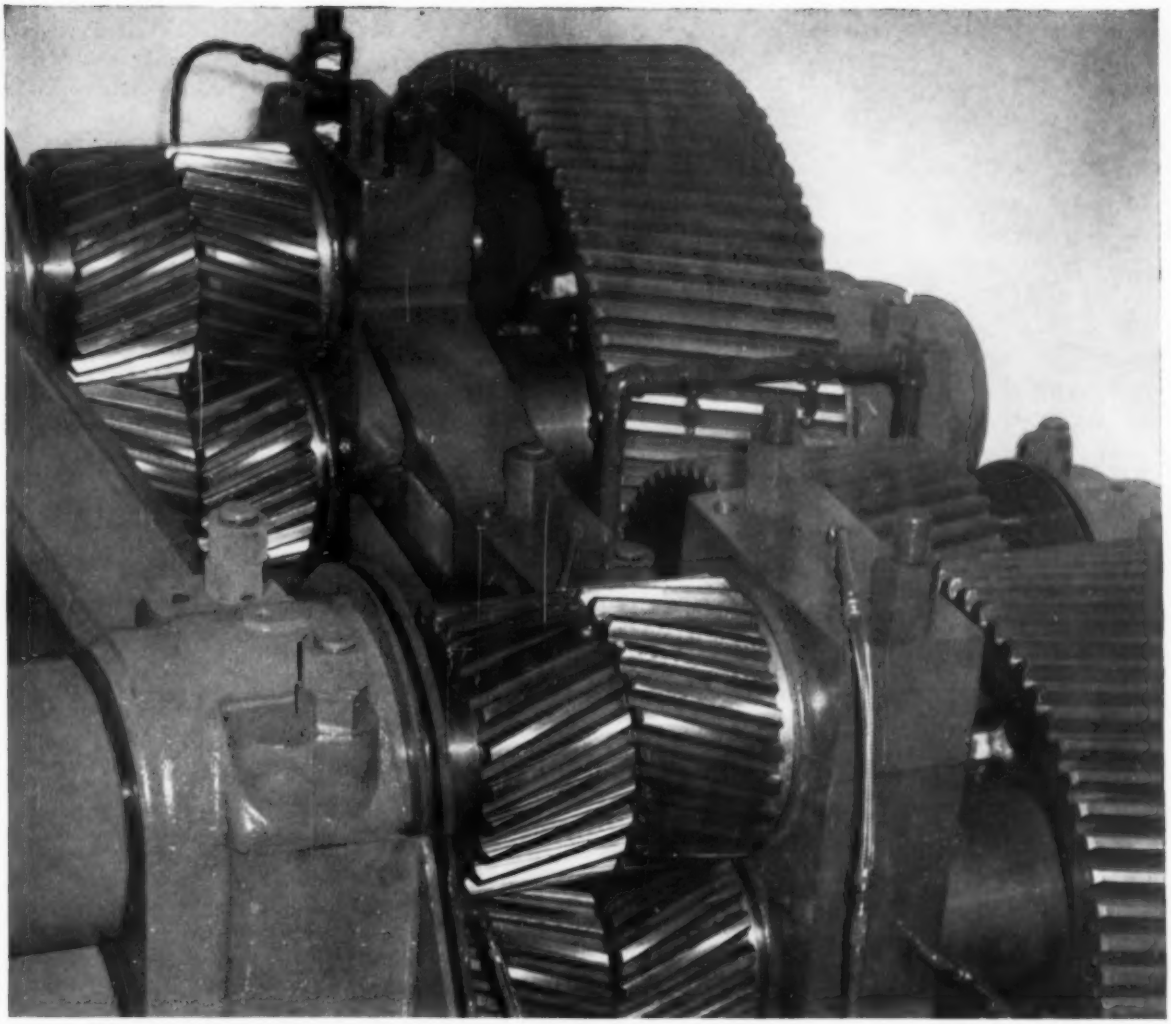
Titanium alloys, particularly the alpha-beta type, lose ductility when hot worked in the beta field without subsequent reduction below the beta transus, or when simply heated into the beta field. For several years, the causes were thought to be beta grain coarsening and alpha envelopes originally surrounding beta grains.

In the past year, research at Battelle has shown the following results:

1. Beta embrittlement is caused by coarse grains that develop rapidly in the beta field, not by grain boundary or acicular intragranular alpha.
2. Loss of ductility is greater when the overheated alloys are in the high-strength condition.
3. The degree to which different alloys are susceptible to "beta embrittlement" is related to their resistance to grain growth in the beta field.
4. Impact properties do not depend on grain size.

These findings are shown, in part, by Fig. 10, which demonstrates the effect of prior beta grain size on tensile ductility. Of the three alloys, the Ti-2.5 Al-16 V alloy retained the smallest grain size and the best ductility after the beta treatments. Why this particular composition should be less sensitive to grain growth in the beta field is not known. However, these results suggest that it should be possible to develop titanium alloys with even greater resistance to grain coarsening, hence with greater ability to be forged, extruded and rolled at higher temperatures.

As fabrication problems are overcome, design engineers devise new uses for this light and strong metal. Even as this article goes to press, some of the information contained in it will be outdated, but this is a healthy sign of a rapidly advancing technology.



Rolling mill pinions of Type 4620 nickel-molybdenum steel have a good hard case (500/550 Brinell) plus toughness, stand up to severe overloads. Made by Morgan Construction Company, Worcester, Mass.

4620 Nickel alloy steel gives them 4 times longer service

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This case stood up – the 4620 nickel alloy steel pinions have served over *4 times longer* than the old through-hardened pinions . . . and are still going strong.

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Parts that take a beating in heavy equipment must also have practical service life – you get both in nickel alloy materials.

For practical information on 4620 nickel alloy steel and its application to your specific metal problems, write Inco's Development and Research Division.

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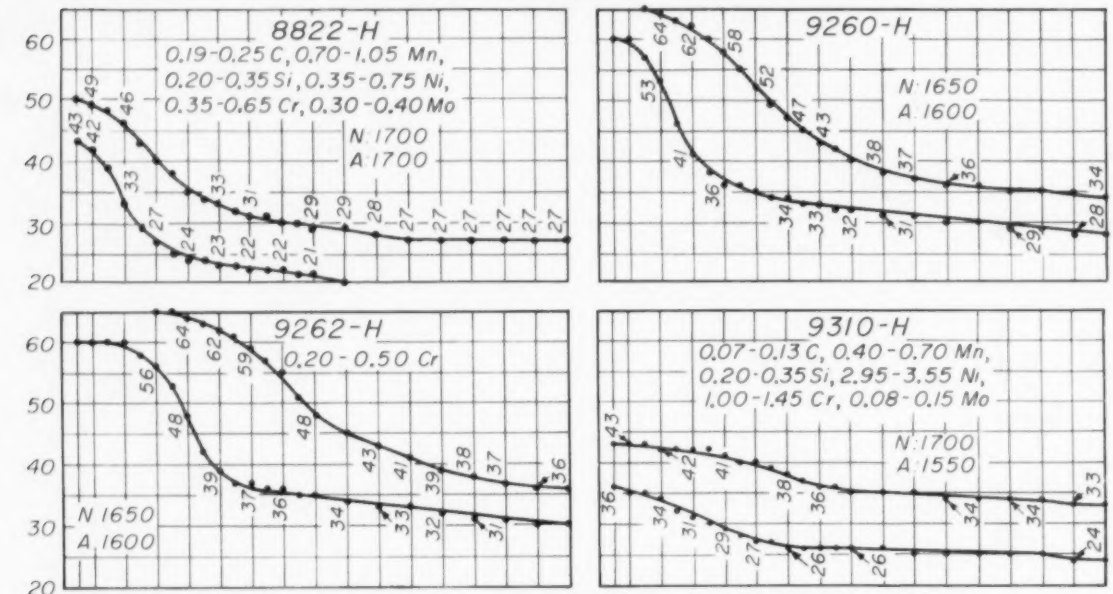
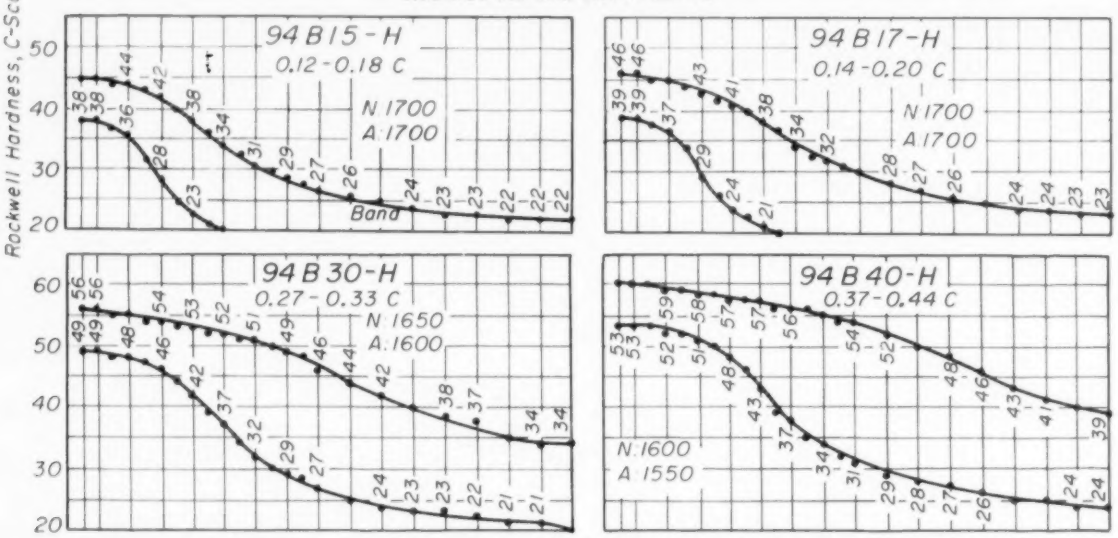
A.I.S.I. List of June 1958

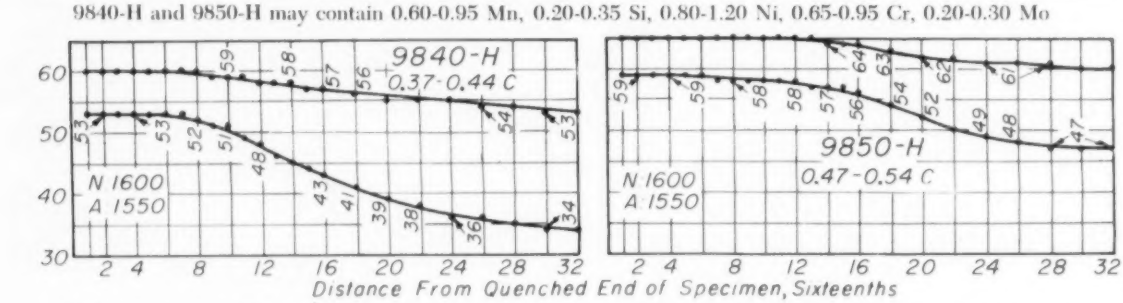
926x-H Series varies as to chromium. It may contain 0.55-0.65 C, 0.65-1.10 Mn, 1.70-2.20 Si.



94 B xx-H steels may contain 0.70 to 1.05 Mn, 0.20-0.35 Si, 0.25-0.65 Ni, 0.25-0.55 Cr, 0.08-0.15 Mo and 0.0005 min. B



9840-H and 9850-H may contain 0.60-0.95 Mn, 0.20-0.35 Si, 0.80-1.20 Ni, 0.65-0.95 Cr, 0.20-0.30 Mo



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

***Experience**—the added alloy in **Allegheny Ludlum** tool steels*

Careful addition of sulfur to melt guarantees typical sulfide distribution, as shown in photomicrograph of longitudinal specimen of EZ MACHINING tool steel.

Sulfur addition to melt held to narrow range in Allegheny Ludlum's EZ MACHINING GRADES

Uniform, finely-distributed sulfides mean uniform machining, uniform high finish, uniform long tool life order after order

Adding sulfur, actually an impurity, to a tool steel melt to make it free-machining must be done with care and precision. That's why Allegheny Ludlum maintains an extremely close average range in adding sulfur to its EZ MACHINING grades. But mere range, however narrow, is not enough. A-L has developed special techniques in adding sulfur and nucleating agents to produce the uniform, finely-distributed sulfides that characterize good free-machining tool steels.

A-L's extra care means you can standardize your machining operations from piece to piece and order to order. This reproducibility is reflected in uniform *machining;* uniform *high finish;* uniform *long tool life.*

For example, in the production of hobs these machining properties in Allegheny Ludlum's EZ MACHINING steels minimize the costly "backing off" operation for back clearance of multiple teeth, eliminating complicated extra heat treatment. Lower residual stresses are set up, because the steel has a lower resistance to the cutting action. Naturally, hobbing is only one of the situations where these free-machining characteristics can benefit you.

Allegheny Ludlum stocks a complete line of tool steel sizes and grades. Call your nearest A-L representative; you'll get quick service and counsel on such problems as heat treating, machining, grade selection, etc. Or write for A-L's publication list which gives full data on the more than 125 technical publications offered. They'll make your job easier. ***ALLEGHENY LUDLUM STEEL CORPORATION, Oliver Building, Pittsburgh 22, Pa. Address Dept. MP-16***

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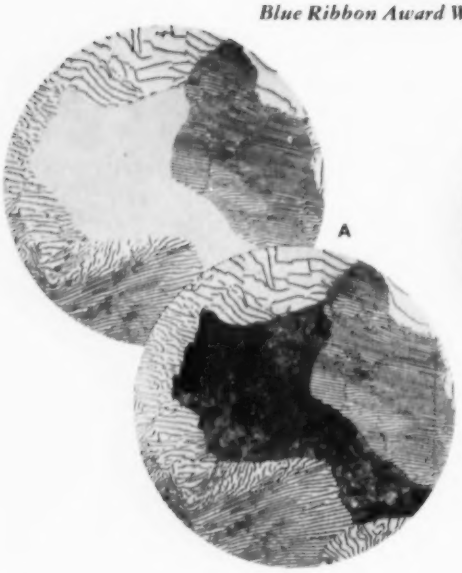
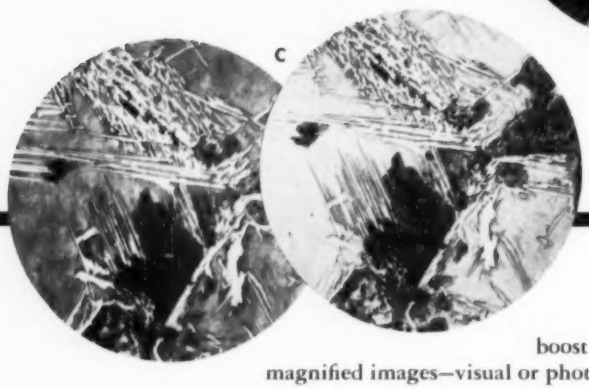


HIS AWARD-WINNING PHOTOMICROGRAPHS, MADE WITH A BAUSCH & LOMB METALLOGRAPH—"Sodium Bisulphite as an Etching Reagent for Steel."



A: Picral Etch—Sodium Bisulphite Etch

B: Picral Etch—Sodium Bisulphite Etch

C: Picral Etch—Picral and Sodium Bisulphite

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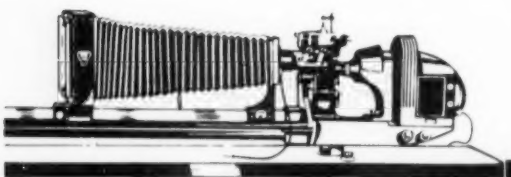

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A Managing Director for A.S.M.

The appointment of Allan Ray Putnam as managing director of the American Society for Metals has been announced by Clarence H. Lorig, president of the Society.

In his announcement, Dr. Lorig said, "In Mr. Putnam we have found an extremely able man skilled in the direction of educational and scientific societies. His association with A.S.M. will bring vigorous leadership to the Society's members and to its staff."

As managing director of the Society, Mr. Putnam will occupy a new position established by the Board of Trustees following the death last May of William H. Eisenman, national secretary and executive head for 40 years.

In commenting on his appointment, Mr. Putnam said, "In this challenging time of technological change in the metals industry, there is a need for great emphasis on educational services to A.S.M. members who are so important in advancing our industry. I look forward to the challenge of this assignment and to the opportunity of working with the Board of Trustees, the staff and the members of A.S.M. in furthering the growth of this influential Society."

Ray Putnam comes to A.S.M. from the American Society of Tool Engineers where he was assistant executive secretary. He has been active in the Council of Engineering Society Secretaries and currently serves as its president. He was president of the National Assoc. of Exhibit Managers in 1955.

Under his able and energetic leadership, the Society looks forward to continued growth in stature and service to its members in keeping with A.S.M.'s increasingly important role in this age of rapid technological development.

Aircraft and Missile Problems Spur Successful Western Metal Congress

STAFF REPORT

Technical sessions on A.S.M.'s program arranged by local committee included topics on selection criteria for materials; forum discussions on carbon control in heat treating and hydrogen embrittlement; panel discussions on vacuum melted alloys, and reduction of warpage. Welding of high-strength metals for pressure vessels was an important theme which ran through many of the technical sessions of A.S.M. and those arranged by the American Welding Society. The Metallurgical Society of A.I.M.E. held sessions on materials for extremely high temperatures, and radiation effects on materials. Inspection methods for honeycomb and advances in ultrasonic and eddy current testing were lively topics at sessions of the Society for Nondestructive Testing. A.S.M.'s special program on explosive forming indicated a great potential for this new process. (A-general)

"THE NEXT MAJOR STEP in aircraft performance will be high mach number planes for both military and commercial purposes . . . Materials to withstand temperatures potentially as high as 1200° F. (from air friction heating) for sustained periods are needed . . . These materials must also stand up under heating and cooling cycles for an adequate service life . . .

"To fulfill this need, the aircraft industry is examining a whole new group of materials. These include toolsteels, titanium alloys, precipitation hardening steels, and for the more severe applications, refractory metals, such as molybdenum, tantalum and columbium; ceramics, such as oxides and borides, and cermets. However, there will still be room for many aluminum alloys in areas where the temperature must be kept at a reasonable level . . . We expect to expand applications for aluminum with the advent of new alloys such as X 2020 and others . . ."

Thus spoke E. A. Green, department manager of production engineering at Lockheed Aircraft Corp., in the opening paper at the A.S.M. session on selection criteria of materials for airframes, power plants and missiles at the Western Metal Congress in Los Angeles last month. What he said was typical of the interest in both the old and the new in materials, fabrication methods and testing techniques, as engineers seek ways to solve problems of space age production.

Criteria for Design — Mr. Green went on to point out that structural design criteria vary with location in the airplane. Thus, a portion of each airframe structure is critical in compression, tension or stiffness. Obviously, the aircraft engineer must know the strength-to-weight ratio of all the materials he deals with to meet the new flight conditions.

Lockheed is using steel heat treated to strength of 260,000 to 280,000 psi. in applications where weight saving justifies the added cost. Landing gear components are an example. It's estimated that the Electra airplane would be 300 lb. heavier if the lower heat treat range of 190,000 to 210,000 psi. had been used. Crack propagation tests reported by Mr. Green showed that AM 350 (see *Metal Progress*, March 1959, p. 116) is by far the most tear resistant steel available. Because of this, it is used for ducts in vital structures operating at 600° F. and 160 psi.

Turboprop Engines

Following Mr. Green, E. L. Bolin, plant metallurgist at Allison Div., General Motors Corp., reported that considerable increase in horsepower of the same basic turboprop engine design has been realized by taking advantage of increases in turbine temperatures. This has required changes in materials for higher strength at increased temperatures in certain areas of the engine.

The major parts in the turboprop gear box include a 4340 propeller shaft driven through a planetary system of carburized 9310 gears. Ball bearings are made from 52100 and roller bearings of carburized 8620 steel. This box is supported by two struts and a torque shaft housing tied into an air inlet housing made of cast AZ 92 A magnesium alloy.

Two Steels Are Used – The compressor has 14 stages of wheels and blades with matching stators. Type 410 steel is used in the second through thirteenth stages. The first and fourteenth stages employ 9310 steel, which is electroless nickel plated; compressor case quadrants are precision cast Type 410 steel.

In the combustion section (mostly sheet metal construction) both Type 310 steel and Hastelloy X are used. The outer case is made of 4130 steel protected from corrosion with electroless nickel plating. The vanes of the nozzles are constructed of Stellite 31 alloy, turbine wheels are made of Inco 901, and GMR 235 D is used in turbine blades. These components operate through a temperature drop of greater than 1600° F. at the first stage nozzle to less than 1000° F. in the fourth stage, which permits the use of S-816 blading with a turbine wheel of A-286 at this location.

Missile Power Plants

Rocket engines pose many material problems and the selection criteria are extremely stringent because of unusual environmental conditions in various parts of the engine. The goal of minimum weight consistent with reliable performance must be met to an even greater extent than in conventional aircraft engines.

In discussing power plants which use liquid propellants, Paul R. Vogt, assistant chief engineer, Rocketdyne Div., North American Aviation, stated that temperature extremes to which materials are subjected are probably greater than in any other engineering situation. The flame temperature of 5500° F. can only be handled by vigorous regenerative cooling of the combustion chamber structure. This is done so effectively that the chambers can be made from conventional materials such as nickel and 4130 steel.

Fig. 1 – General Chairman, R. H. (Bob) Gassner, Chief Metallurgist of Douglas Aircraft's El Segundo Div., Opens the A.S.M. Sessions at the Western Metal Congress. Each speaker was provided with a unique nameplate of titanium which had been chemically milled*

High-temperature problems are more difficult in the gas generator and turbine sections of the engine because cooling is less practical here than in the combustion chamber. In these areas materials commonly used in jet engines are widely used, such as Inconel X, Stellite 21 and 16-25-6. Newer alloys being investigated are René 41, A-286 and Inco 713 C.

Subzero Environment – Low-temperature problems are by far the most critical. Liquid oxygen, now employed as oxidizer, has a temperature of –300° F., and liquid hydrogen which is being considered as a fuel goes down to –423° F. Even at –300° F., the designer is pretty much limited to nickel-base alloys, austenitic steels and aluminum because of the brittleness problem. Thermal contraction aggravates seal problems.

*Contributors to the speakers' nameplates were as follows: Commercially pure titanium sheet, Titanium Metals Corp. of America; chemical milling, Turco Products, Inc.; forming, Douglas Aircraft Co.; blue anodic coating, Sanford Process Co. and W. D. Nelson, Douglas Aircraft Co.

Solid Rocket Chambers

The suitability of a material for a particular chamber application depends upon obtaining the proper combination of mechanical properties needed. In discussing this subject, L. E. Zwissler, head, applied studies, Polaris Development Engineering Div., Aerojet-General Corp., emphasized that the traditional tensile test which measures ultimate strength, yield strength and ductility in terms of per cent elongation and reduction of area under conditions of uniaxial loading is merely the starting point. It is necessary to measure mechanical properties and toughness of the material under the biaxial and triaxial loading conditions actually encountered in service.

Mr. Zwissler said that up to now steels have been used in fabricating large high-strength rocket motor cases for solid propellants, because they offer the best compromise of availability, ease of fabrication and reliability. He listed the following steels as being most likely to give the required mechanical properties: A.I.S.I. 4340, AMS 6434, Tricent, Super Tricent, UHS 260, MBMC No. 1, Ladish D 6 A, Aircool X-200, VascoJet 1000, Unimach II, Peerless 56, and Halcomb 218.

Titanium in Future Picture – Alloys of titanium offer potential advantages over steel in attaining the maximum strength-to-weight ratio for motor cases. However, there are fabrication problems which must be solved before it can be used for light-weight, reliable pressure vessels.

Fig. 2 – Fiery Gases Stream From Rocket Engine During Static Test Firing at Rocketdyne's Field Laboratory Near Los Angeles. Materials needed and fabrication methods for rocket motors were topics for numerous discussions at the Western Metal Congress

Materials for Petroleum and Power Uses

The second session on selection criteria dealt with materials for petroleum, chemical and power generation applications. G. Robert Prescott, research engineer, C. F. Braun & Co., brought out the fact that hydrogen sulphide, at elevated temperatures, corrodes steel and low-chromium alloys at an excessively high rate. Not only is metal loss a problem, but scale formation within acceptable limits of corrosion may be too high to maintain catalyst activity in many processes. Mr. Prescott mentioned this interesting point: Short-time corrosion tests indicate that iron-aluminum alloys offer extremely high resistance to hydrogen sulphide corrosion.

In discussing power generation equipment, G. B. Grable, chief metallurgist, Bechtel Corp., stated that today's challenge for plants fired with fossil fuels is to find materials with adequate strength for service above 1050° F. The austenitic steels look promising, but are expensive and introduce fabricating problems. He predicted that within the next ten years this challenge will be met by metallurgists, and operating temperatures approaching 1300° F. may become practical.

Vacuum Melted Alloys

The need for higher quality materials in aircraft and missile manufacturing continues to spur the development of vacuum melting by induction and the consumable electrode arc melting method. Vacuum production facilities now available in the United States for steel and superalloys can produce 27,000,000 lb. per year by induction melting and 75,000,000 lb. by arc melting. Expansion by industry now underway will increase the capability of the latter vacuum proc-

ess to about 100,000,000 lb. this year. These figures were given by W. W. Dyrkacz, manager of quality control, Watervliet (N.Y.) Works, Allegheny Ludlum Steel Corp., in a session on how advances in mill practices have improved material characteristics.

Mr. Dyrkacz went on to point out that both of the vacuum melting processes have given birth to a new series of high-temperature alloys, such as Udimet 500, M-308, D-979, René 41, and super Waspaloy. Iron and nickel-base alloys of this type containing a combined total of titanium and aluminum of about 3 to 6% could not be produced to consistent quality by air melting.

Double Melting – In superalloys, special high quality can be obtained by employing induction vacuum melting for very close chemistry control, then tapping the heat into electrode form and remelting the same composition by the consumable electrode vacuum process. This gives an alloy with the best center ductility, highest degree of soundness and the least amount of segregation. Vacuum processing also improves the reliability of low-alloy steels, such as the 5% Cr hot die steels (now being studied for structural uses), Types 4340 and 52100, A. Nagy, research associate, Universal-Cyclops Steel Corp., reported.

Fabrication in Limelight

An important theme which ran through many of the technical sessions of the cooperating societies was the efficient use of the high-strength metals, both new and old. This involves fabrication methods, of course, and about the only available joining method is welding. Here we immediately run into trouble, for you take sheet or plate (a rolled and heat treated product) and join it with a seam which is essentially a long thin casting. Even though the casting may be flawless and the chemical composition carefully watched or adjusted, you are immediately introducing an as-cast nonhomogeneity into the hot worked structure, to say nothing of heat affected strips separating the casting from the sheet.

As Dwight Gunder of Polaris Co-Ordination said in his vivacious statement of the problem in the joint A.S.M.-A.W.S. Session on Pressure Vessels, metallurgical irregularities can be as potent as geometric irregularities in reducing the service capabilities of rocket fuel tanks and similar containers. Portions which have too much metal may be more dangerous than the regions which are underdesigned. Even though we now have in commercial production sheet and thin plate which can be heat treated to yield strengths of 300,000 psi. in the standard tension test, it is his belief that the best pressure vessels now being made will start to yield under internal pressures which stress the shell at 225,000 psi. (He was of the opinion that this figure would be increased to 240,000 psi. within the next year, and to 275,000 psi. by the mid-1960's.)

Mechanism of Fracture – As a matter of fact, metal which has, say, 250,000 psi. ultimate tensile strength in the standard A.S.T.M. test piece, if made into a vessel with such skill that when burst under internal pressure, the fracture is in the body rather than in a joint, the computed tensile stress at explosive failure will always be considerably lower than the figure supposed to apply to the material itself – by as much as 10%, actually. This phenomenon is ascribed to the circumstance that in the simple tension test there is some chance for ductile flow in two directions even in the narrow gap between yield and fracture; there is always the possibility for a little "necking down". In a pressure vessel, however, the metal is resisting biaxial stress, so the ability to flow is sharply restricted. However, engineers and designers in this field are paying a good deal of attention to the "shattering tendency" of the metal. (It may be related to the ability to stop a crack, once started, so desirable in ordinary ship plate.) Furthermore, much reliance is being placed on burst tests of small vessels, not only to determine the actual strength of the sheet material but also the effect of minor variations and adjustments in the manufacturing techniques. It also appears that the results vary considerably with the cleanliness of the alloy, and with minor variations in the chemical analysis even within the spread allowable in the specification.

Vessels From Hot Die Steels

The use of such small test vessels was described in detail by G. F. Harkins, chief process engineer of Solar Aircraft Co., in the first session held by the American Welding Society. He confined his attention to the various 5% Cr hot die steels now available under various trade names. The problem was to devise optimum fabrication techniques for fuel tanks for missiles, wherein the tank forms part of the casing and may be as big as 54 in. diameter and 30 ft. long. Such pieces are too big to fabricate by the spinning process; a seamless forging would have much too thick a wall; welding of thin plate is the only practicable manufacturing method for quantity production, despite the difficulties involved.

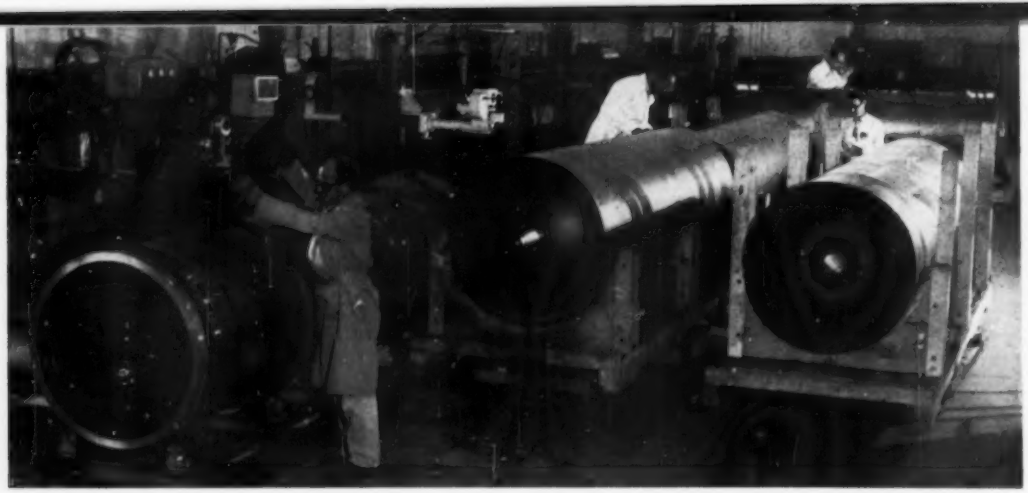


Fig. 3 – One Important Theme Which Ran Through Many of the Technical Sessions at the Western Metal Congress Was the Efficient Use of High Strength Metals for Pressure Vessels, such as Those Shown Above in Production at Solar Aircraft Co.

Favorable Properties – In Mr. Harkins' opinion, the 5% Cr, 0.40% C alloy with 0.50% V has better strength-to-weight properties in the 400 to 1000° F. range than any of the titanium, aluminum or molybdenum alloys, 17-7 PH or the Inconels. It is air hardenable, so heat effect along the weld is minimized. Final shaping is done while the metal is at 1050° for the final tempering, and this produces a hardness of Rockwell C-50 to 52 and the best performance under proof test (small vessels to bursting) – especially it gives a high degree of reproducibility and this reliability is judged much more important than any single high test value.

Production of various sized tanks requires sheet of various thicknesses from 0.040 to 0.25 in. The thicker plates are welded with submerged arc, and it was noted that the flux adds alloying elements to the weld, an effect which varies greatly with small variations in the voltage. Recommended techniques are to make a root pass with a 1/16-in. filler wire of the same analysis, filling the joint but welding not quite through. Then the vessel is annealed for stress-relief, and finished with a second pass, welding clear through with tungsten-argon arc, using strong fixtures and a copper backup strip. The edges of very thin sheet are hot upset in a roll welder, abutted, welded with tungsten inert gas ("tig") process, and these longitudinal joints roll-planished down to thickness to refine the grain and increase the ductility of the weld.

Thin-Walled Aluminum Tanks

Mass production of 450-gal. external fuel tanks of thin-gage aluminum alloy sheet was described by R. J. Longerbeam, process engineer for Royal Industries, Inc. Since daily output means one mile of weld per day, the more rapid "mig" (metal electrode, inert gas) process is used, it being capable of 90 in. per min. on 0.072-in. butt welded joints in 6061 S alloy. These tanks are of aerodynamic shape, with conical ends and tapered cylindrical bodies. The ends are spun but the bodies are welded as cylinders and then blown up in a "pot" to the correct tapered shape.

In discussion, it developed that it was rather common practice to weld thin-walled structures slightly small, place them in a strong container of accurate internal shape, and blow them up to size. The few per cent of yield not only takes out warpage and buckling and gives smooth surfaces but it also irons out or a least equalizes the internal stresses left from the fabrication operations. It also is a good proof test!

Vessels of PH Stainless Steel

Pressure vessels of 17-7 PH and 17-4 PH received much praise from Russ Meredith, senior research engineer in the missile laboratory of North American Aviation, Inc. He cited a long list of advantages such as low crack sensitivity, no postheat or preheat necessary, corrosion resistance, good weldability resulting in few rejections, low distortion during fabrication. These items are of large diameter and too thin in the wall to be heat treated after fabrication.

Since uniform and tight joints are a prerequisite, a closely controlled automatic welding procedure must be devised, and strong accurate fixtures employed. Even with "tig" welding, a more uniform weld is promoted by using a so-called "No ox" cup – a small, shoe-shaped refractory container riding along with the welding head within which the helium or argon protective gas is contained. Mr. Meredith reported one unexplained result of a series of tests on butt joints where the sheets were purposely mismatched or out of surface alignment. Smooth

abutment is demanded by designers but the test showed far less weakening in mismatched joints than stress analysis predicts.

Since thin-walled work of this sort requires fairly rigid fixtures, the question was asked: "How do you get the last fixture out of a closed tank?" The answer was: "In corrosion resistant vessels, make the internal support of aluminum and dissolve it out by caustic solution."

Fabricating Superalloys

The nickel-base family of ultra-high-strength alloys are valuable because of their high strength at high temperature. This same property makes forging or primary working much more difficult. Donald E. Nulk, senior project engineer, design metallurgy, Thompson-Ramo-Wooldridge, Inc., reported on techniques for forging these hard to handle alloys. Higher capacity equipment is necessary. Because of the complex chemistry of the alloys the forging range is quite small and any attempt to get above the normal range results in hot shortness or, in extreme cases, liquidation.

Mr. Nulk recommended that in press operations rather heavy reductions should be made in the early stages of forging with a minimum of somewhere around 8 to 10% reduction in the final operation if physical properties are to be maintained. On the other hand, hammer operations usually dictate a series of light blows and many heat treating cycles.

Alloy A-286 – Methods used at Ryan Aeronautical Co. for fabricating this alloy were given by L. J. Hull, chief metallurgist. He pointed out that A-286 can be readily cold formed in the solution treated condition where the hardness is below Rockwell B-90. However, the alloy work hardens rapidly and stress-relieving or annealing at 1650° F. or higher may be required between stages in severe forming operations. He stated that Ryan's experience has shown the forming characteristics to be similar to 19-9 DL or Type 410 stainless steel.

If trouble is experienced, the most practical solution lies in more frequent stages during forming to stay below the critical range in reduction between annealing operations. The alloy can be fusion and resistance welded if special precautions are observed. Mr. Hull predicted a bright future for A-286: "It may be the next skin material for high mach planes or missiles. Its use in jet engines will no doubt be expanded."

Type 431 Stainless – Reliable high-strength parts can be made from Type 431 stainless steel if proper techniques for fabricating and processing the alloy are followed, according to C. C. Angstadt, assistant chief metallurgist of Douglas Aircraft Co.'s El Segundo Div. Mr. Angstadt stated that when fully hardened to a minimum tensile strength of 200,000 psi., it offers the best corrosion resistance of all the hardenable stainless steels. Details of methods developed by Douglas for fabricating parts using more than 8,000,000 lb. of Type 431 stainless will be presented in an early issue of *Metal Progress*.

Materials for Extremely High Temperatures

The Metallurgical Society of the A.I.M.E. held a session on materials for extremely high working temperatures (above 2000° F.). Graphite is a very interesting example, and, as pointed out

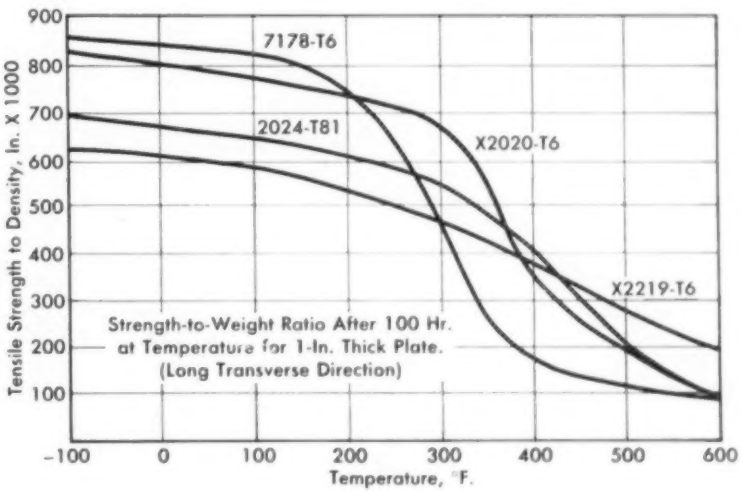


Fig. 4 – First Aluminum Alloy to Go Into Production Which Requires Atmospheric Control Is X 2020, Containing a Nominal 1.1% Li, 4.5% Cu, 0.5% Mn and 0.2% Cd. It has high mechanical strength at elevated temperatures in the 300 to 400° F. range, as shown by these curves presented by E. H. Spuhler, manager of Aero-Space section, Aluminum Co. of America. High properties of X 2020-T 6 are obtained by heat treating and artificial aging

by Leon Green of Aerojet-General Corp., it has been rather extensively used for rocket guide vanes, re-entry cones, and liners for burners. Another interesting possibility is elements for nuclear propulsion systems for rockets – although in this connection beryllium oxide just about reaches the maximum for any known nonmetal, above the melting point of molybdenum and tungsten.

The last mentioned metals were discussed at considerable length by Marion Semchyshen of Climax Molybdenum Co. The best alloy so far to reach experimental production contains 0.5% Ti, 0.08 Zr, and 0.02 C. (The carbon in this vacuum melted alloy is slightly more than enough to insure proper deoxidation and apparently functions as a precipitation hardening element.) The alloy has a short-time strength of 55,000 psi. at 2400° F. One rather large difficulty remains to be surmounted: These strong solid-solution alloys are almost impossible to work. It is believed that hot working temperatures are from 3500 to 4000° F. – far above the 2400° maximum for the ordinary tools for steel fabrication. (Diamond cuts diamond; maybe we'll have to build rolls and extrusion equipment of molybdenum or tungsten!)

Molybdenum-Tungsten Alloys – Even more refractory alloys are found in the Mo-W system. A 70% Mo, 30% W alloy is in experimental production. Other alloys are still in the research stage, but a 75% Mo, 25% W, 0.10% Zr alloy is the strongest now known: 73,000 psi. in short-time test at 2400° F. The modern techniques of manufacturing these basic metals and alloys to give high purity (oxygen, nitrogen and hydrogen each less than 1 ppm.) enable the metallurgist to dope these alloys with precise amounts of addition elements. Mr. Semchyshen was very hopeful that interstitials, controlled in this way, would result in even stronger materials.

Speaking in behalf of pure tungsten, Robert W. Hall of Lewis Research Center, National Aeronautics and Space Administration, mentioned that thoriated tungsten filaments (with about 1% thorium oxide, primarily to prevent grain growth) have tensile strengths of about 30,000 psi. at 3500° F., and 10,000 at 4500° F.

Heat Treating and Plating

Two well-attended forum sessions considered problems of carbon control in heat treating steel rocket cases and hydrogen embrittlement of ultra-high-strength steels. The requirement for heat treating missile cases of steels such as 4130 and 4140 is becoming closer and closer on specifications for decarburization. Careful control of endothermic atmosphere will control decarburization to less than 0.003 in. (maximum allowed by specifications). Another test requires that the surface hardness drop be less than 20 points Knoop as determined by the Tukon microhardness traverse. (A most significant panel discussion on reduction of warpage by die quenching and other thermal treatments will be reported in a future issue of *Metal Progress.*)

Embrittlement Relief – Parts made from 4340 steel heat treated above ultimate tensile strength of 180,000 psi. when stressed above 60% of yield strength are subject to delayed failure because of embrittlement from hydrogen or corrosion. Several approaches are being followed to avoid embrittlement in deposition of cadmium: (*a*) vacuum metallizing; (*b*) plating of thin or porous cadmium deposits at high current densities; (*c*) use of modified cadmium plating baths. It was reported that Lockheed has developed a cadmium plating solution which has no effect on reduction of area and notch tensile strength (even without baking).

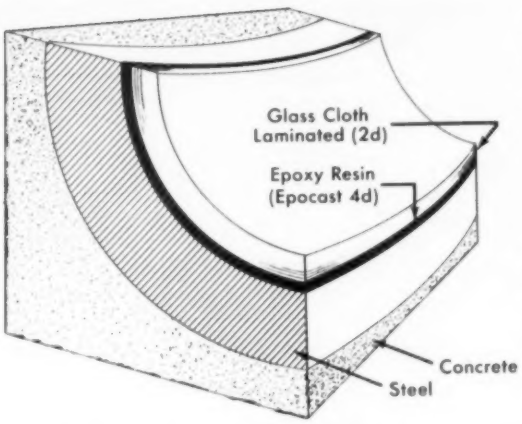
Cadmium plate must be porous to permit relief by baking. Severe embrittlement in plated parts cannot be relieved by this method. Baking has been found to increase the embrittlement in some instances. A sustained load test, such as the stress ring described in *Metal Progress* for February 1959, page 90, is more reliable than a short-term test.

Some high-strength steels are susceptible to stress-corrosion cracking, which resembles hydrogen embrittlement. A distinction between these two fundamentally different mechanisms can be made in the laboratory by observing the effect on cracking behavior when a small electric current is passed through a stressed specimen immersed in the corrodent.

Testing and Inspection

A large proportion of the meetings held by the Society for Nondestructive Testing were devoted to problems in the aircraft industry. A typical item which requires much testing is "honeycomb" which is being used more and more by the aircraft builders because it provides structural integrity with light weight. Honeycomb paneling now makes up the major structure of many of the newer airplanes and missiles.

Such parts must meet stringent specifications, but honeycomb appears purposely designed to provide inspectors with the maximum number of



Success of sessions devoted to explosive forming presented by A.S.M. went far beyond expectations. Discussions indicated that the great potential of metal forming by explosive charges has just been tapped. But technical know-how for this new method is meager and there is a critical need for data which can be used by design engineers. Shown above is a cross section of a die for explosive forming suggested by Furane Plastics, Inc. Explosive methods will be particularly useful for forming parts of tough high-temperature metals needed to withstand aerodynamic heating encountered in high-speed aircraft and the fiery blast of jets and rockets. Shown below is the high energy forming facility installed by Ryan Aeronautical Co. In the process, a metal blank is placed in a die and the assembly lowered into the pit which is filled with water. A charge of explosive is positioned within the die. When detonated the explosion forces the water against the part and into the shape of the die.

headaches. Each of the countless small cells which form the interior must be adequately bonded (by brazing or adhesion) to the skin. Since the skins cover the comb, the bonds cannot be seen, and must be examined indirectly by radiography or ultrasonic testing. These test methods, known to be successful in examining heavy sections, had to be adapted to thin skins. In the few years since honeycomb was introduced, its testing has taxed the ingenuity of many engineers. The reports presented at this meeting proved that most of the problems have been solved.

The "C-Scan" – This method, developed by Ultrasonic Testing and Research Laboratory, was one of the most versatile test methods discussed. As presented by Hugh Mitchell of that organization, the device incorporates a memory tube similar to a television screen. The information is gathered by ultrasonic waves and converted to an electron beam whose intensity varies with the unity of the bond. This beam "writes" a picture of the honeycomb on the screen of the tube. Resolution is 30 to 40 lines per in. As first evolved, this device was limited by the size of the picture tube, even though an area three times the size of the screen could be displayed. Since that time, adaptations have allowed the incorporation of a recorder which is much like the "facsimile" machines used by press agencies to transmit pictures. Now, large panels can be tested; the beam "writes" the honeycomb picture on long strips of paper. This test is suitable for large, fairly uniform panels and can be easily automated.

Panels With Complex Curves – Honeycomb panels with irregular curves such as those needed for wings, rudders and other surface parts are difficult to test. They require elaborate handling so that all areas can be properly inspected. Since testing can be accomplished with radiography and fluoroscopy, it is not necessary to immerse the part. However, the inspector must be protected from radiation. To meet these requirements, X-Ray Products Corp. erected an elaborate manipulation setup now in use at North American Aviation.

As described by Justin Schneeman, president of X-Ray Products, the part, held in place by nylon tape, is positioned in a yoke which can be moved horizontally and vertically. The operator, who is protected by heavy shielding, can also rotate the yoke along the horizontal and vertical axes, as well as move it backward and forward. Other controls enable proper positioning of the

X-ray machine. Through this setup, an operator can expose any area of an intricately curved surface to the X-ray beam so that the quality of its bond can be determined.

Ultrasonic Testing

Several papers were concerned with various aspects of ultrasonic methods. For example, R. C. McMaster of Ohio State University discussed contoured and focused transducers. With flat transducers, which are generally used, it is difficult to pick up small flaws and defects which are angled to the plane of the ultrasonic wave. If curved lens elements are attached to flat transducers, waves can be focused within a small area and at any point below the surface. Since the sound energy is concentrated, a small defect will reflect more energy; this results in a stronger signal. According to Mr. McMaster, proper design of lens elements will enable ultrasonic testing of many forms of curved surfaces, such as tubes and fillets.

Aircraft Landing Gear – Ultrasonic testing is often employed to locate flaws in landing gears. R. E. Kleint of Ultrasonic Testing and Research Laboratory offered much information on methods for testing these items. Since the parts are round, flat transducers do not produce an adequate signal. An immersion technique in which the landing gear is placed in a tank and revolved on its long axis is needed. Meanwhile, the crystal is offset about half the diameter. Signals from radial flaws can easily be picked up by this method.

Titanium Pressure Vessels – This application of ultrasonic testing came about when Convair-Astronautics had difficulty in rating these welds by radiography. Since the vessels (made of 6% Al, 4% V alloy) were spherical, an acceptable image was hard to obtain by conventional methods. E. R. Foor, engineering metallurgist at Convair, mentioned that the greatest problem was lack of fusion between passes; this led to rapid failure under test pressures. Longitudinal and shear wave techniques made it possible to check these welds for porosity and lack of fusion. Both methods are being used successfully at Convair.

Pulse-echo techniques now enable measurement to thicknesses down to 0.050 in. even though both surfaces are exceedingly rough or corroded. The method is being applied to corrosion and delamination studies, according to Donald Erdman, assistant to the president, Sperry Products, Inc.

Eddy Current Testing

Today, eddy currents are being used for many different applications, and engineers add more continually. One unusual application, brought out by Richard Hochschild, president of Metrol, Inc., concerned temperature measurement. It seems that molds used by Corning Glass Works require extremely accurate control. Through eddy current testing, temperatures can be determined within 2° F. accuracy up to 930° F.

B. E. Justice, superintendent of the quality control department at Convair's Fort Worth, Tex., installation, discussed several practical applications of eddy current testing. Their units are portable and are used to separate and test the hardness of aluminum alloys. Hardness testing, in fact, is simplified considerably; now, large skins, wing sections, and parts attached to the airframe can be easily tested. Such parts are difficult to test by conventional means.

Problems of Specifications

In the aircraft and missile industry, specifications are a major problem, particularly in materials and parts supplied to the fabricators. Two sessions were devoted to panel discussions (called Workshop Sessions) in which producers and users of parts and materials attempted to work out some of their differences. For example, Leo Schapiro, chief metallurgist, Douglas Aircraft Co., and Roy Paine, chief metallurgist, Aluminum Co. of America, presented their views on testing of aluminum extrusions and forgings. After discussions by R. E. Kleint (Ultrasonic Testing and Research Laboratory) and J. L. Waisman (Tatnall Measuring Systems), groups composed of attending members tried to find areas of mutual agreement. Some of the suggestions were:

1. Before contracts are written, producer and user should spell out the required specifications.
2. More research (with better instrumentation) is needed to evaluate defects.
3. Inspection should be based on an adequately marked *finish* drawing.
4. Inspection should be done by the producer.

All in all, the meetings at the Western Metal Congress were very productive, and left those attending with much to think about during the coming months. The Exposition was equally successful. Some 480 firms demonstrated to 63,000 visitors way to make products better and cheaper with new materials and improved processes.

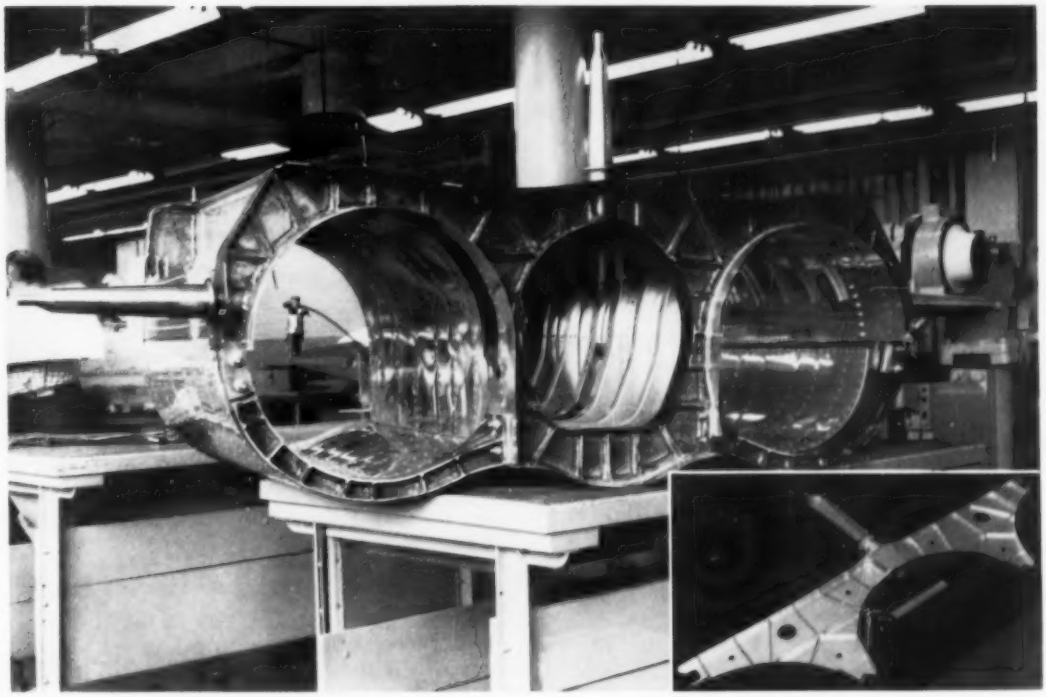


Fig. 1 – Welded Mock-Up of Fuselage Frame Assembly. Inset shows vertical spindle fuselage frame (79 × 44 × 5 in.) outlined in mock-up

Fabricating and Finishing Toolsteels for Aircraft Parts

*By P. E. RUFF**

H-11 maintains high strength at elevated temperatures. Formability is similar to that of 4130, and weldability is like that of 4340. Parts are limited to a 4-in. thick section to obtain through hardening on air cooling. Most parts require coatings for corrosion protection. Specific procedures for processing H-11 are given. (Q-general, J-general, G17k, K9s; TS, SGA-h)

IN LAST MONTH'S ARTICLE ("Hot Work Toolsteels for Aircraft"), we discussed the advantages of H-11 as a material for structural parts in today's supersonic aircraft and missiles (see Fig. 1). Though lacking corrosion resistance, the alloy can be heat treated to strengths of 280,000 to 300,000 psi., and it retains its strength up to 1000° F. Properties of the steel create fabrication problems. Techniques developed at North American Aviation to form, weld, heat treat, and finish H-11 will be given here.

Forming H-11 steels in the annealed condition

*Engineering Specialist – Metallurgical, North American Aviation, Inc., Columbus, Ohio. This is the second of two articles on toolsteels in aircraft.

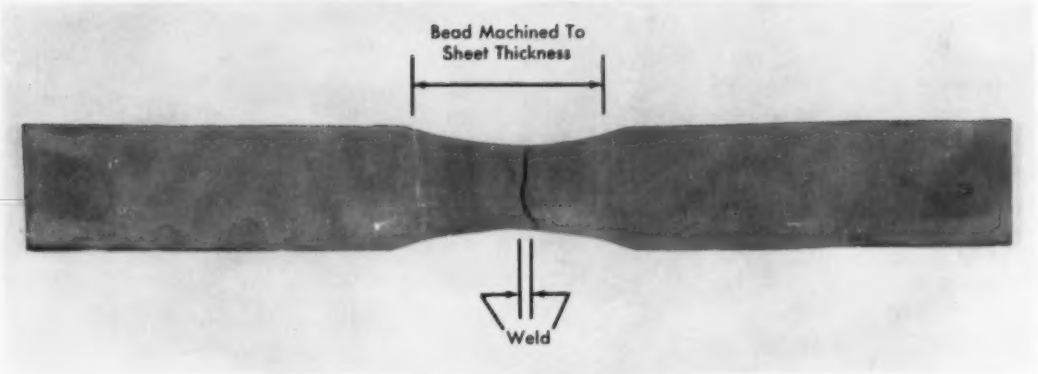


Fig. 2 – Specimen Cut From Welded Sheet. The bead is machined flush before heat treatment. A ½-in. gage length was used so that only the ductility of the weld area would be tested. (Properties are given in Table 1)

is not difficult; formability is similar to low-alloy steels such as 4130. Production parts have been made with power brake, punch press, hydropress, stretch press and drop hammer. Most forming is done at room temperature using a minimum bend radius of 3 t. Brake forming is routine.

Punch press operations, usually performed with a beryllium-copper die, are highly recommended. The result is a part in which little, if any, hand forming is required. Joggling is done in a punch press die with minimum runout being four times the depth of joggle. The hydropress method is not desirable due to the large (12° average) springback. Stretch wrap forming has been very successful with maximum stretch and shrink of 16% and 8%, respectively. Drop hammer forming is usually done with a zinc-base female die and a lead punch. A forming method which will produce a finished part from the press is desirable; indentations and gouges can result from hand working. No forming is permitted in the hardened condition.

Hot work die steels are readily machinable in the annealed condition (not unlike annealed 4340); some parts are machined at Rockwell C-36 to 40 before final heat treatment to improve surface finish. After final heat treatment to ultra high strength levels, machining is difficult. Rigidity is most important; stock and tools must be firmly clamped, and machines must not be allowed to vibrate. Tool life is short and maintenance costs are high due to frequent grinding. Carbide tools operating at about 100 to 150 sur-

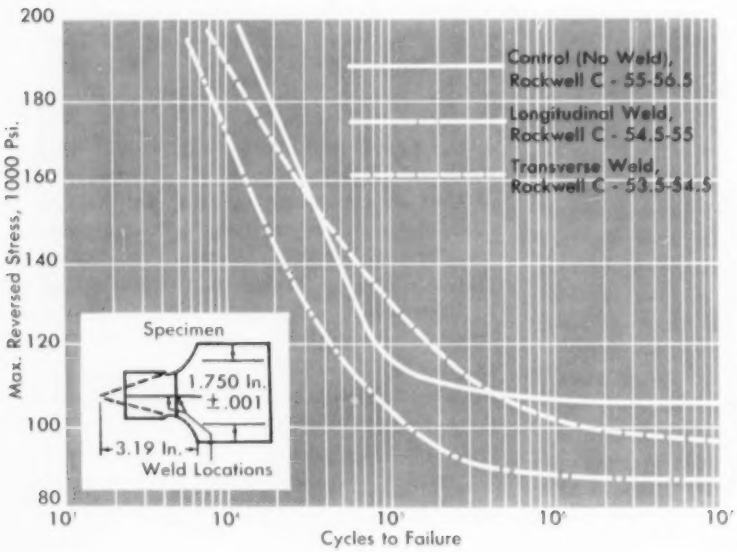


Fig. 3 – S-N Curves for Transverse and Longitudinal Welds. All specimens are rough machined and heat treated. Then 0.005 in. is machined from each side, and finish machined to shape

Table I – Mechanical Properties of Fusion Welded H-11 Alloy Steel Sheet, 0.078 In. Thick (See Specimen in Fig. 2)

Tempering Temperature	Specimen	Ultimate Strength	Elong. in 0.5 In.	Rockwell Hardness		Min. Bend Radius, 180°
				Base	Weld	
950° F.	Avg.*	296,700 psi.	0	C-54.5	C-54.0	10 t
	High	319,300	0			
	Low	269,700	—			
975	Avg.*	295,900	12.7%	C-53.5	C-52.5	4 t
	High	297,400	15.4			
	Low	293,100	11.0			
1000	Avg.*	294,800	11.4	C-52.5	C-52.0	5 t
	High	289,900	12.2			
	Low	282,200	10.3			
1025	Avg.*	266,500	11.3	C-51.0	C-49.5	5 t
	High	267,900	11.9			
	Low	264,300	10.8			

*Average values are based on four specimens.

Table II – Effect of Tempering Temperature on Mechanical Properties

Tempering Temperature	Yield Strength	Ultimate Strength	Elongation	Rockwell Hardness
950° F.	230,500 psi.	305,700 psi.	4.0%	C-57.0
975	226,600	296,700	5.6	C-56.5
1000	228,800	280,400	5.7	C-52.5
1025	222,200	264,400	5.7	C-52.5
1040	214,400	250,400	5.3	C-50.0

face ft. per min., with plenty of coolant (water soluble oil), give the best performance. Interrupted cuts are extremely difficult.

For these reasons, parts are generally finish machined before final heat treatment except for close-tolerance surfaces; these are ground after final heat treatment. After grinding, all parts are stress-relieved at 925° F. for 2 hr.

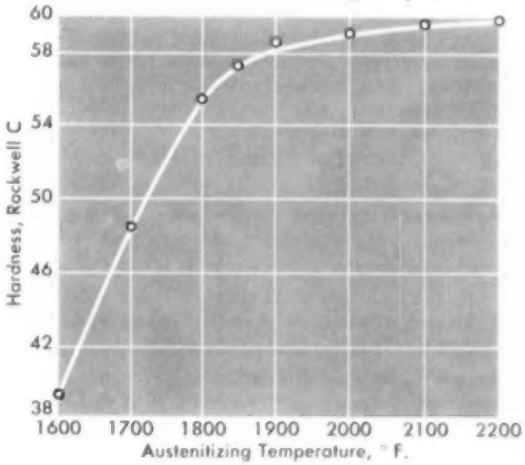
Welding of H-11

Weldability is good if proper precautions are observed. Those used for welding 4340 steel are also necessary for H-11. Fusion welding is done with a tungsten arc with inert gas shielding. (In experimental work, filler wire was swaged from strips sheared from H-11 sheet.) Parts to be welded are preheated to 250° F. minimum. After welding, parts are stress-relieved in a jig at 400 to 500° F. for 1 hr., prior to cooling at room temperature. When completed, the weldment is stress-relieved at 1200° F. for 2 hr.; final heat treatment follows. Radiographic, magnetic particle, and other nondestructive methods are used to inspect weld quality.

Table I shows mechanical properties of welded H-11 sheet (0.078 in. thick) as a function of tempering temperature. It was found that tempering at 975° F. gave optimum properties – highest strength combined with maximum elongation and bend ductility. Tempering at 950° F. resulted in brittle welds.

Tests were also made to find out how fusion welding affects fatigue strength of sheet. The S-N curves are shown in Fig. 3. From a practical standpoint, transversely welded specimens showed no difference in fatigue strength when compared to control specimens, except at lifetimes close to the endurance limit. However, specimens welded longitudinally showed a reduction in fatigue strength. The difference

Fig. 4 – Variations of Hardness With Austenitizing Temperature for H-11. These hardnesses are obtained by quenching the material from the indicated austenitizing temperatures



can be explained. In transversely welded specimens, bending can occur in the base metal rather than in the weld. However, for longitudinally welded specimens, the weld bends, and thus acts as a metallurgical notch.

Heat Treatment and Processing

Heat treatment of H-11 steel is complex. A high austenitizing temperature is required. As the austenitizing temperature increases (Fig. 4), more carbides are dissolved in the austenite and grain size increases. This gives austenite of higher carbon content which causes higher hardness on quenching. Therefore, to minimize grain growth and decarburization, it is best to use the lowest austenitizing temperature which will adequately homogenize the austenite and give sufficient "as-quenched" hardness. The alloy is air hardening in the sizes used for aircraft parts. This minimizes warpage, dimensional change and quench cracking.

At about 900° F., there is a secondary hardening* peak; tempering above 950° F. causes the hardness to drop rapidly, as Fig. 5 shows. Table II shows effect of tempering temperature on mechanical properties.

Corrosion Protection

H-11 lacks corrosion resistance and requires surface protection. Because of the danger of hydrogen embrittlement at the 280,000 to 300,000-psi. level, these alloys cannot be electroplated. For temperatures up to 250° F., two coats of zinc chromate primer (Specification MIL-P-6889) are used on interior parts for corrosion protection. From 250 to 375° F., an enamel (Specification MIL-E-7729) is used; above 375° F., aluminized silicone enamel is employed.

Electroplated coatings are avoided. In certain applications where plating is necessary, nonembrittling coatings, such as vapor deposited cadmium and "Electrolized" chromium, are employed. Other nonembrittling methods of plating are under investigation. These include vapor-plated aluminum, vapor-phase deposition from carbonyls, and electrodeposition from nonembrittling baths.

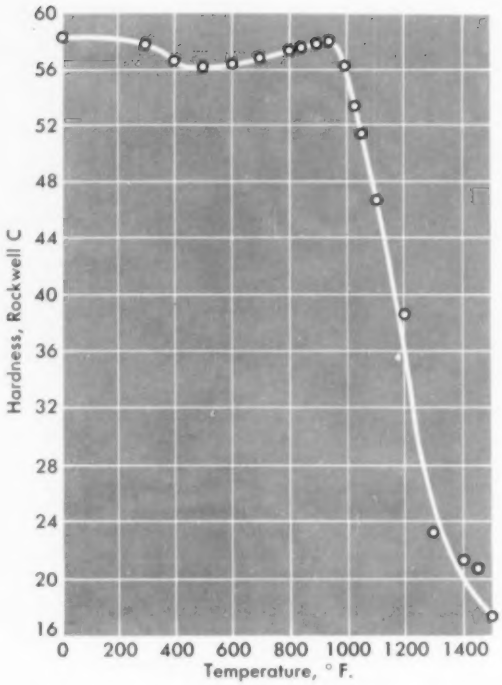


Fig. 5 – Hardness as a Function of Tempering Temperature. Note rapid drop in hardness above 975° F. The steel was austenitized at 1850° F.

*"Secondary hardening" is thought to result from two causes: To begin with, toolsteels usually retain much austenite after hardening. When tempered at about 900° F. (depending on the austenitizing temperature), complex carbides precipitate from residual austenite. This apparently makes the austenite less stable, and it transforms to martensite on cooling. Both the complex carbides and the transformed martensite probably account for secondary hardening. Since this newly formed martensite must also be tempered (and internal stresses relieved), multiple tempering is necessary.

Heat Treating and Processing Procedures for Structural Parts From H-11

Heat Treatment

Furnaces – Salt bath or controlled atmosphere furnaces are used unless parts will subsequently have all surfaces machined. Surfaces must be completely free of carburization, and have no more than 0.003 in. total decarburization.

Section size is limited to thickness of 4 in. to insure uniform response to heat treatment.

Preheating – Large, complex parts, and parts having abrupt changes in section size, are preheated at 1200° F.

Austenitizing – Heating for hardening is done at 1850 ± 25° F. for time shown in Table III, depending on section thickness.

Quenching – Parts are cooled in still air from

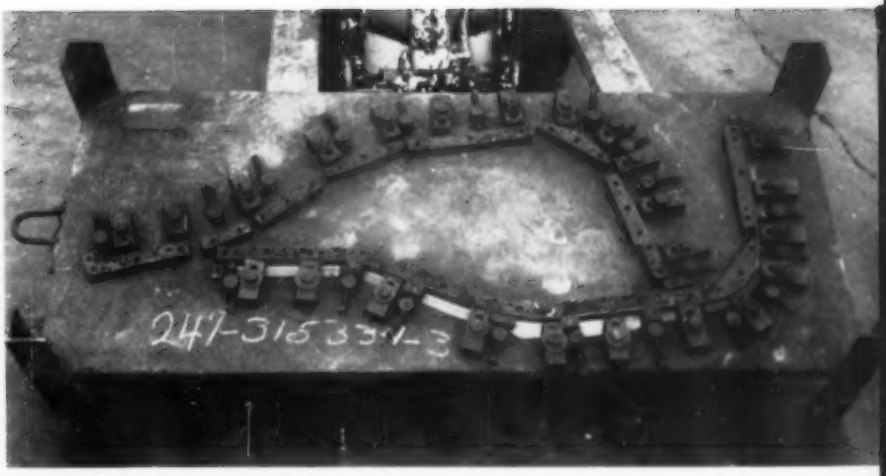


Fig. 6 – Formed Extrusion Positioned in Temper Jig

the austenitizing temperature to room temperature. They are suspended or supported to minimize nonuniform cooling.

Tempering – Triple tempering minimizes retained austenite. First, the parts are double tempered at 975° F. (each temper lasts 2 hr.) and checked for hardness. Retempering for 2 hr. follows at the temperature indicated in Table IV. Parts are air cooled to room temperature between each heating. Tempering below 975° F. is prohibited (because of the secondary hardness peak). Tempering should be started as soon as possible, and, in any event, within 4 hr. after hardening.

Straightening, when necessary, is done with jigs during tempering. First, parts are stress-relieved at 375 ± 25° F. for 2 hr. after hardening. Then, they are positioned in a temper jig as in Fig. 6. Only slight adjustment in contour is permitted on sheet metal parts after final tempering. Straightening of parts other than those made from sheet metal is prohibited.

Stress-Relief – As soon as possible after grinding or other stress-inducing operation, parts must be stress-relieved at 925 ± 25° F. for 2 hr.

Annealing is accomplished by heating at 1650 ± 25° F. for times shown in Table III, furnace cooling to 800° F. (or lower) and air cooling.

Process annealing at 1450 ± 25° F. for 2 hr. softens hardened parts and relieves stresses.

Reheat Treatment – Parts previously hardened from 1850° F. may not be rehardened from this temperature unless they are first annealed. This is necessary to avoid discontinuous grain growth which can occur upon rehardening from the same austenitizing temperature.

Intermediate Heat Treatment – Before final heat treatment, parts (except sheet material) may be heat treated to Rockwell C-40 maximum for grinding operations or rolling threads. This treatment aids machining, and helps reduce distortion during final heat treatment. It is accomplished by hardening at 1650 ± 25° F., for times shown in Table III, and double tempering at 1150 ± 25° F. for 2 hr.

Protective Coatings – Copper plating before heat treatment is prohibited due to surface embrittlement. At the high hardening temperature, copper diffuses into the grain boundaries and causes loss in ductility.

Inspection

Magnetic Particle – All parts are inspected by this method after finish machining (or grinding and plating) and before shot-peening or other cold working processes.

Hardness tests determine conformance to tensile strength requirements after tempering. Table V shows the hardness-tensile strength relationships used by North American Aviation.

Decarburization – After final heat treatment, parts must be free from decarburization to the extent that the average hardness must conform to Table VI listings. Testing is not needed if finish machining has removed decarburization.

Tensile Tests – When required by blueprint, tensile specimens from the same heat of material are used to check heat treatment and processing.

Cleaning and Finishing

Cleaning – Parts must be free of contamination before heat treating. Parts heat treated in salt baths must be soaked immediately in hot water (185 ± 10° F.) to remove all residue from internal and external surfaces.

Scale and oxide removal is accomplished mechanically by methods such as sand-blasting, grit blasting and wet (vapor) blasting to prevent hydrogen embrittlement. Pickling and cathodic cleaning are prohibited.

Temporary Corrosion Protection – Immediately following scale or oxide removal, parts are degreased and coated with rust preventive compound (MIL-C-15074).

Table III – Minimum Soaking Times for Annealing and Hardening (1850 ± 25° F.)

Diameter or Thickness of Max. Section	Air and Atmosphere Furnaces		Salt Bath Furnaces	
Up to 0.249 in.	0 Hr., 25 Min.		0 Hr., 18 Min.	
0.250—0.500	0	45	0	35
0.501—1.000	1	0	0	40
1.001—1.500	1	15	0	45
1.501—2.000	1	30	0	50
2.001—2.500	1	45	0	55
2.501—3.000	2	0	1	0
3.001—3.500	2	15	1	5
3.501—4.000	2	30	1	10

Table IV – Tempering Temperatures

Rockwell Hardness*	Third Tempering Temperature†
C-53 to 54.5	975° F.
C-55 to 55.5	1000
C-56 to 56.5	1025
C-57 and over	1050

*After double tempering at 975° F.
†280,000 to 300,000 psi.

Plating and Hydrogen Embrittlement Relief – Electroplated coatings are avoided due to the danger of hydrogen embrittlement. If plated coatings are necessary, stringent procedures for embrittlement relief are required.

Cadmium – Only vapor-deposited cadmium is used; cyanide or fluoborate cadmium plating is prohibited. Vapor deposited cadmium can be employed for operating temperatures up to 500° F. No embrittlement relief is required.

*"Coralloy Type Y"** is applied for service in the 500 to 800° F. range. Surfaces to be coated are shot-peened prior to plating. Within 8 hr. after plating, parts are baked at 375° F. for 23 hr.

Chromium is used for service up to 700° F. where required for a hard surface. Surfaces are shot-peened before plating.† Within 8 hr. after plating, parts are baked at 625° F., for 2 hr., followed by 375° F. for 23 hr.

Electrolized chromium‡ is employed for higher operating temperatures (500 to 800° F.) Within 8 hr. after plating, the parts are baked at 375° F. for 23 hr.

Hard nickel plating is limited to parts where wear and corrosion resistance are both required below 400° F., or where corrosion resistance only is needed up to 800° F. Before plating, surfaces to be coated are shot-peened. Within 8 hr. after plating, parts are baked at 375° F. for 23 hr.

Electroless nickel is useful for large parts which are hard to plate because of its better throwing power and improved uniformity of coating. Its hardness can be increased to Rockwell C-60 by heating at 750° F. for 1 hr. Operating temperatures are limited to 750° F. Parts are baked at 375° F. for 23 hr., within 8 hr. of plating.

Aluminum – Spray metallized and vacuum-deposited aluminum coatings are being used for corrosion protection up to 925° F. – the maximum operating temperature of H-11 alloy steels. No embrittlement relief is required.

Gold – Because of their low emissivity, solution-type gold coatings* are applied to reduce service temperatures. No embrittlement relief is required.

Shot-peening is used to improve fatigue life where required. It is also required upon surfaces to be "Coralloy" plated, chromium plated, or nickel plated.

*"Coralloy Type Y", a nickel-zinc alloy plating, is a proprietary process of Rockwell Spring and Axle Co., Coraopolis, Pa.

†The bath consists of 30 to 34 oz. per gal. chromic acid plus 0.30 to 0.34 oz. per gal. H_2SO_4 in water. It is operated at 135° F. and 3.0 to 5.0 amp. per sq.in. A proprietary bath is also used.

‡Electrolizing is a proprietary process of the Electrolizing Corp., Chicago Heights, Ill.

Table V – Hardness-Tensile Strength Relationship

Rockwell Hardness		Brinell Hardness	Tensile Strength
C-Scale	A-Scale		
C-50	A-76	488	256,000 psi.
C-51	A-76.5	500	264,000
C-52	A-77	512	273,000
C-53	A-77.5	524	283,000
C-54	A-78	536	292,000
C-55	A-78.5	548	301,000

Table VI – Decarburization Requirements

Rockwell Hardness, Core	Rockwell Hardness, Surface	
	Minimum	Maximum
C-50—50.5	A-74	A-77
C-51—51.5	A-74.5	A-77.5
C-52—52.5	A-75	A-78
C-53—53.5	A-75.5	A-78.5
C-54—54.5	A-76	A-79
C-55—55.5	A-76.5	A-79.5
C-56—56.5	A-77	A-80

*This coating is common in the ceramic industry. The liquid is sprayed, dried, and heated to produce a film of metallic gold.

Short Runs

Brazing Gear Shift Levers

THE WARNER GEAR DIV., Borg-Warner Corp., produces a gear shift lever by hardening and brazing in a cyanide bath, then quenching in a fast quench oil. Since the lever is to shift transmission gears, it is essential that the hardened end be hard and tough enough to resist wear and fatigue throughout the vehicle life, despite continual use under all types of operating conditions. Further, the fulcrum ball which positions the lever at the proper point for assembly into the transmission must be securely brazed to the lever itself.

The lever is 1030 steel and the fulcrum ball 1213 steel. Both parts are machined to the proper dimensions and assembled before hardening. Since the ball is brazed to the lever, a ring of brazing alloy is first placed in a groove cut into the fulcrum ball. The ball is then pressed onto the lever at the required distance from the lower end as shown in the photograph.

Batches of levers are heated in a 40% sodium cyanide bath for 40 min. at 1500° F. (A minimum of 40% cyanide is required to maintain sufficient fluidity, to produce a good brazed joint, and to develop the desired case depth in the time allowed for hardening.) Cyanide salt is added periodically to the bath to maintain the required concentration.

Essentially, the hardening procedure is one of carbo-nitriding. Both nitrogen and carbon diffuse into the surface after breakdown of the sodium cyanide. The lower hardening temperature reduces distortion, eliminates cracking, and insures a ductile core. After being brought to heat, the brazing ring is liquid; the closed groove in the fulcrum ball prevents escape.

The levers are unloaded from the pots and placed in a steel-mesh basket suspended in a 1500-gal. tank of Voluta Oil 23 (Shell Oil Co.) at about 120° F. The oil temperature is not

Gear Shift Lever and Assembled Fulcrum Ball Before Hardening, and After Hardening and Bending. Both brazing and hardening are done simultaneously

critical. The lower ends of the levers are quenched completely over the fulcrum balls for about 5 min. After quenching, they are washed in a hot alkali bath to remove oil and salt.

For testing, the lever is clamped in a vise, and struck on the ball-tip end with a hammer. It must bend about 10° without failing. The fulcrum ball is tested at the same time. The surface must be file hard (equivalent to a minimum of Rockwell C-60). If the spot check shows any levers to be questionable, 100% inspection follows. They are then sent to the forming department where they are bent about 6 in. above the fulcrum ball to accommodate different positions required in the vehicle's cab. A fast quench oil was needed in this application to give the uniform surface hardness required and provide core properties that would enable the lever to bend when tested.

X-Ray Dimension Gage

A DIMENSION GAGE manufactured by Industrial Gauges, a department of Daystrom-Weston Industrial Div., uses an X-ray beam to control the production of 0.00035-in. aluminum foil to ±2% – or to seven millionths of an inch. This type of equipment can also measure hot or cold reduced strip and pipe walls with accuracy.

When preset tolerance limits are exceeded, a signal sends the data needed for correction.

The gage is simple in operation. An X-ray beam about as wide as a pencil passes through the strip being measured and the transmitted electromagnetic energy is collected by a receiver unit. This signal is converted into an electrical impulse which is transmitted to the main console. Here, the energy absorbed from the X-ray tube is computed and then converted into convienient units, which indicate thickness dimensions, and finally into signals, which indicate the needed correcting action.

Gages employing infrared radiation are used to measure dimensions during hot rolling. They scan across fast moving metal strip. Any change in relation to the strip edges is projected onto a time axis; this is then converted into a continuous indication of strip width. Continuous determination of widths from 3 to 100 in. or more can be made at speeds up to 2200 ft. per min.

Like any other vacuum tube, the X-ray tube can be completely turned off when not in use and can be controlled with great accuracy. Because the radiation pattern can be varied at the turn of a dial, it is possible to measure a wide range of materials and thicknesses.

X-Ray Thickness Gage on Four-High Aluminum Mill. As the strip rolls past, its thickness is constantly checked

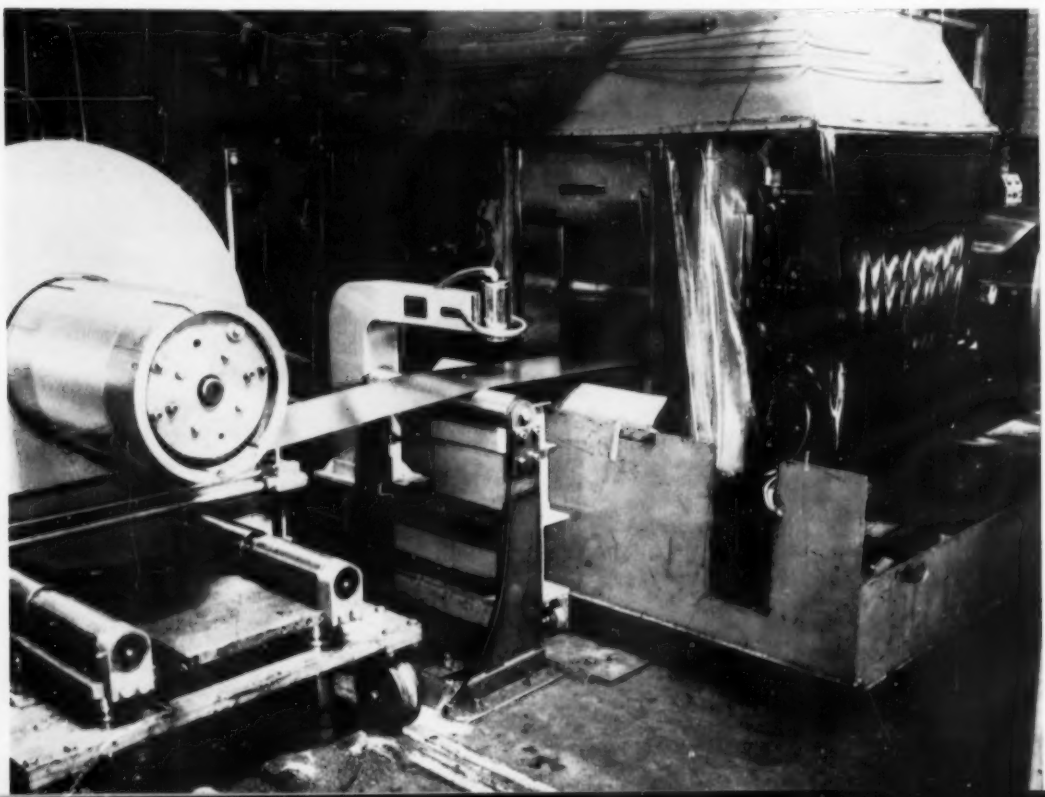


Fig. 1 – Typical High-Strength Parts Made From Prealloyed Steel Powder. (Courtesy Keystone Carbon Co.)

How to Do More With Prealloyed Powders

By W. L. BATTEN*

These powders are produced from molten alloys, and compacts have properties of the composition within limitations of the density achieved. Parts made from alloy steel powders, such as gears and cams, can be heat treated to high strength. A variety of stainless steel and special powders are useful in corrosion resisting, high-temperature and electrical applications. (H-general, H12n; AY, SS, TS)

THE AMOUNT of metal powder used by industry increased rapidly from just before World War II to 1957. Statistics from the Metal Powder Industries Federation show that consumption of iron powder rose from 2,000,000 lb. in 1943 to 57,000,000 lb. in 1957. About 50% of this went into structural parts. Behind this

*Manager, Powder Metallurgy Dept., Vanadium-Alloys Steel Co., Latrobe, Pa.

growth is the fact that more and more manufacturers turned to the metal powder process for faster production, to cut costs or to get special properties which they were unable to obtain by other means.

Parts made from iron powder have a limited tensile strength. Mixtures such as iron and copper or iron, copper and graphite, although having improved strength, still did not fill the gap between sintered parts and castings. Prealloyed steel powders came on the scene in 1948 and opened up new areas for application of high-strength parts made by the powder metallurgy process.

Table I – Physical Properties of Vasco 4630-A Prealloyed Steel Powder

Sieve analysis, U. S. standard	
+100	2%
−100+140	20
−140+200	23
−200+325	30
−325	25
Apparent density, g. per cc.	2.6
Flow time, sec.	30
Weight loss in hydrogen, 2150° F.	0.5%

Compacting Pressure*	Green Density†	Compression Ratio
30	6.2	2.38
40	6.6	2.54
50	6.8	2.62
60	7.0	2.69

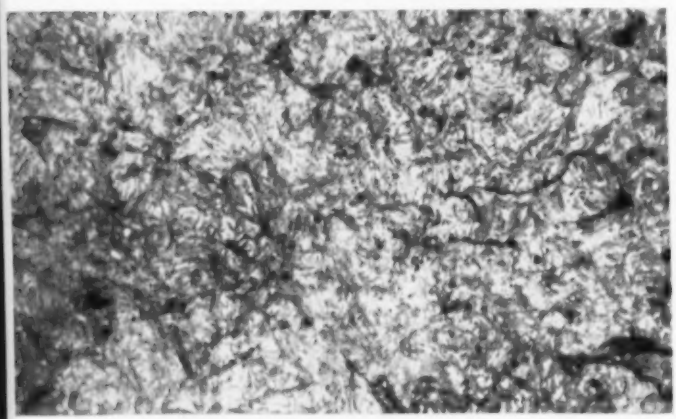
*Tons per sq. in. †G. per cc.

Prealloyed powders are completely alloyed by melting. At Vanadium-Alloys Steel Co., our powders begin as electric furnace melts of the desired chemistry. This molten alloy steel is atomized directly into tiny droplets or particles which can be likened to tiny ingots, each having the composition of the melt. Compacts produced from these alloyed powders are homogeneous and give mechanical properties expected from the composition within the limitations of density achieved.

Although our atomization process will produce a wide range of iron, nickel and cobalt-base prealloyed powders, certain standard grades have proven most useful. For low-alloy structural steel parts, Vasco 4630-A powder, produced to A.I.S.I. 4630 chemistry, is used for gears, cams, pawls, levers, and ratchets. These parts must have high tensile strength, wear resistance and toughness.

The basic 4600 analysis (nickel - molybdenum) is produced with carbon content of 0.10 to 1.50% for special applications. Full annealing following atomization provides workability at all carbon levels although lower carbon powders are slightly easier to press. Composition of our 4630-A steel powder is as follows: carbon 0.30, silicon 0.35, manganese 0.75, sulphur 0.010, phosphorus 0.010, nickel 1.85, molybdenum 0.25. Typical properties of the powder are given in Table I.

Fig. 2 – Tempered Martensite Structure in Heat Treated Parts Made From Vasco 4630-A Steel Powder. Density is 95% theoretical. Oil quenched from 1600° F., tempered at 300° F. Nital etch, 500 ×



Parts Have High Strength

Properties of the 4600 compositions in bar form are preserved in their prealloyed powder counterparts. Compacts made from Type 4630-A respond fully to heat treatment over a wide range of temperature. The high hardenability – a feature of this alloy system – is preserved by homogeneous distribution of alloy content. This permits full hardening, even with heavy sections, in parts weighing over 1 lb. Typical high-strength parts made from prealloyed steel powders are shown in Fig. 1.

Carbon control can be effectively maintained with controlled atmospheres for sintering and heat treating. The tempered martensite microstructure, shown in Fig. 2, for high-density high-strength parts made from 4630-A powder is obtained with a conventional heat treatment, which consists of austenitizing 10 min. at 1600° F., oil quenching, then tempering for 1 hr. at 300° F. This structure gives maximum strength for the grade of powder used. For additional ductility, tempering at 900° F. is recommended.

The mechanical properties given in Table II are obtained by Keystone Carbon Co. on parts (such as shown in Fig. 1) made from 4630-A powder. Gears for an oil pump (Fig. 3) are a typical application where strength, wear resistance and toughness are required. The elonga-

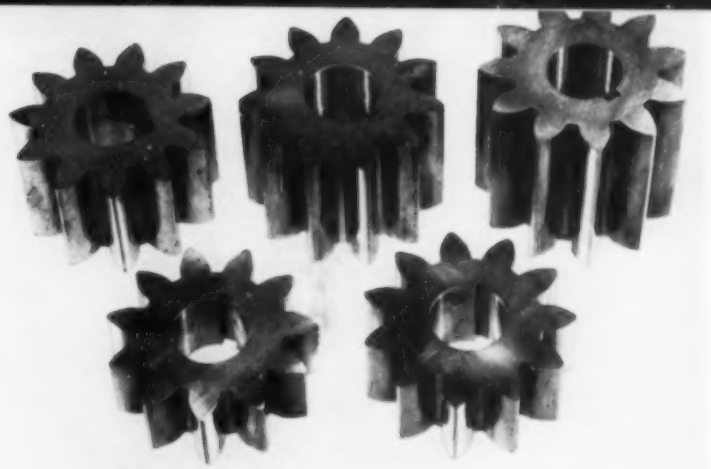


Fig. 3 — High - Strength Gears for Oil Pumps Made From Prealloyed 4630-A Steel Powder. (Courtesy Kalamazoo Div., New York Air Brake Co.)

tion values in Table II do not reflect the true toughness of parts, probably because of the notch effect of residual porosity, even at high densities. The unnotched Izod impact values related to density and tensile strength in the sintered and heat treated conditions are a better measure of toughness. It should be pointed out that impact strength of compacts from 4630-A powder compares favorably with values for high speed steel heat treated to hardness levels commonly employed in single-point cutting tools such as tool bits used for lathe work.*

Curves in Fig. 4 are plotted from composite data on tensile strength and impact energy obtained over the range of densities available to the user of metal powder parts. The tensile specimens were standard M.P.I. bars, 4 in. long with a ¼-in. square reduced section. The impact specimens were unnotched standard A.S.T.M. Izods. Some specimens were prepared by single pressing at 40 tons per sq.in. and sintering at 2100° F. Others were coined and resintered for additional density. Sintering time was 30 min. at temperature in an endothermic atmosphere neutral to carbon content. Curves were plotted from specimens in the as-sintered condition, over the range of densities studied, and from specimens which were heat treated in an endothermic atmosphere by austenitizing 10 min. at 1600° F., oil quenching, then tempering 1 hr. at 600° F.

Molding of high-strength parts is usually done on hydraulic presses, as shown in Fig. 5, because of the high pressures (40 to 60 tons per sq.in.) required. In the photograph, the feed shoe has just cleared the die cavity leaving it filled with powder and ready for the briquetting cycle. Sintering is carried out in controlled atmosphere regulated for the carbon content needed.

Gears made from prealloyed steel powder (Fig. 1) having the mechanical properties illustrated in Table II and Fig. 4 are within these tolerances: radial diameter or dimension perpendicular to direction of molding, ± 0.001 in. per in.; dimension in direction of molding, ± 0.005 in. per in.; concentricity (total indicator reading), ± 0.001 in.; parallelism of gear teeth, ± 0.0002 in. per in.

Surface finish is superior to that obtained by precision grinding and is of the order of 4 to 5 rms. micro-in. In the example of gears for oil pumps, the improved finish gave a quieter, more efficient operation. The metal powder gears also were less expensive. Additional information† on

*"Unnotched Impact Strength of High Speed Steels", by A. H. Grobe and G. A. Roberts, *Transactions* ASM, Vol. 42, 1950.

†Information on properties of prealloyed steel and stainless powders is given in these references:

"Prealloyed Steel Powders and Their Applications", by A. H. Grobe and G. A. Roberts, *Proceedings*, Metal Powder Industries Federation, Vol. 1, 1955.

"Now — High-Strength Alloy Steel Powder Metal Parts," *Product Engineering*, January 1955.

"Mechanical Properties of Stainless Steel Powder", by A. H. Grobe and G. A. Roberts, *Transactions* A.I.M.E., Vol. 191, *Journal of Metals*, February 1951.

Table II — Typical Properties of Steel Parts Made From 4630-A Powder for High-Strength Applications*

	Apparent Density, G. per Cc	
	7.3	6.7 to 7.1
Ultimate tensile strength, psi.	130,000	70,000
Yield point in compression, psi. (0.2% offset)	96,000	65,000
Elongation in 1 in.	1.5%	0.5%
Rockwell hardness, compact	C-30 min.	C-25 min.
Rockwell hardness, particle (by conversion)	C-55 min.	C-55 min.
Radial crushing strength, psi. A.S.T.M. "K" Value	260,000	130,000

*Source: Keystone Carbon Co.

Table III – Physical Properties of Stainless Steel Powders*

	Type 304	Type 316
Mesh size: +100	2%	2%
−100+140	19	19
−140+200	21	21
−200+325	28	28
−325	30	30
Weight loss in hydrogen	0.35% max.	0.35% max.
Flow time	28 sec.	33 sec.
Apparent density, g. per cc.	2.8	2.7
Compression ratio		
30 tons per sq.in. compacting pressure	1.79	1.99
40 tons per sq.in. compacting pressure	1.91	2.16
50 tons per sq.in. compacting pressure	2.01	2.27

*Average values from production lots of −100 mesh powders.

physical properties of prealloyed powders is now available.

Stainless Steel Powders

Another group of useful prealloyed powders is the 18-8 stainless steels. Although A.I.S.I. Types 304 and 316 are the most popular for both filters and structural parts, other stainless grades are used for specialized applications. Because Types 304 and 316 cover so many stainless applications, they have come to be standard powders. Their composition is given below and physical properties appear in Table III.

	A.I.S.I. 304	Type 316
Carbon	0.08%	0.08%
Silicon	2.3	2.3
Manganese	0.8	0.8
Chromium	18.0	17.5
Nickel	8.5	12.0
Molybdenum	—	2.4

Figure 6 shows the relationship of density to tensile strength and percent elongation for compacts from Types 304 and 316 prealloyed stainless steel powders. More detailed properties have been published.*

The designer can use Fig. 6 to obtain the tensile strength and elongation in structural parts at different densities. In this figure, composite data for the commercial range of processing conditions have been plotted. M.P.I. standard tensile bars, 4 in. long with a ¼-in. reduced section were used. Some specimens were processed by single pressing at 40 or 50 tons per sq.in. followed by sintering at temperatures of 2200 or 2300° F. Others were double pressed and sintered for additional density. All sintering was for 45 min. at temperature in dry hydrogen.

*See second footnote on p. 107.

Wrought tensile specimens made of Type 304 bar stock, annealed by heating 45 min. at 2200° F. (dry hydrogen) had a tensile strength of 102,000 psi. with elongation in 1 in. of 72%. The microstructure shown in Fig. 7 is typical for parts with 75% of theoretical density, obtained by single pressing at 40 tons per sq.in. and sintering at 2200° F. Except for porosity, this structure is comparable to wrought 304 in the annealed condition.

In addition to good tensile strength and excellent elongation for parts made of stainless steel powder, the engineer will find the corrosion resistance and appearance expected of stainless. He can choose from a wide variety of finishes ranging from an as-sintered matte to a burnished shiny finish. As with wrought parts, best corrosion resistance is obtained with a highly polished surface. Production parts made from prealloyed stainless powders are shown in Fig. 8.

Fig. 4 – How Density of Compacts Made From 4630-A Steel Powder Affects Tensile Strength and Impact Energy

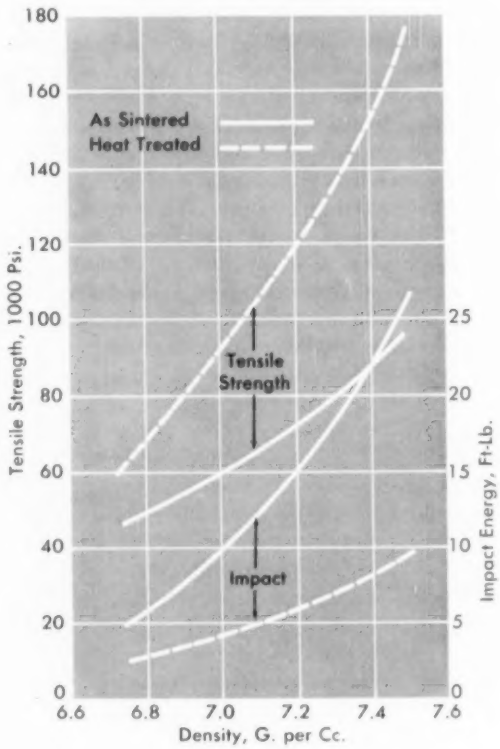


Fig. 5—Tooling Setup Used to Press High-Strength Gears. The feed shoe has just cleared the die cavity, leaving it filled with powder and ready for the briquetting cycle. (Courtesy Keystone Carbon Co.)

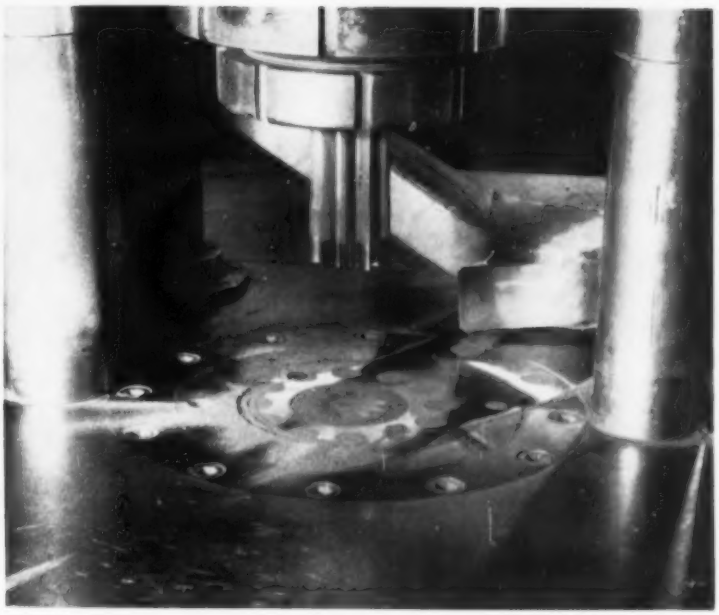
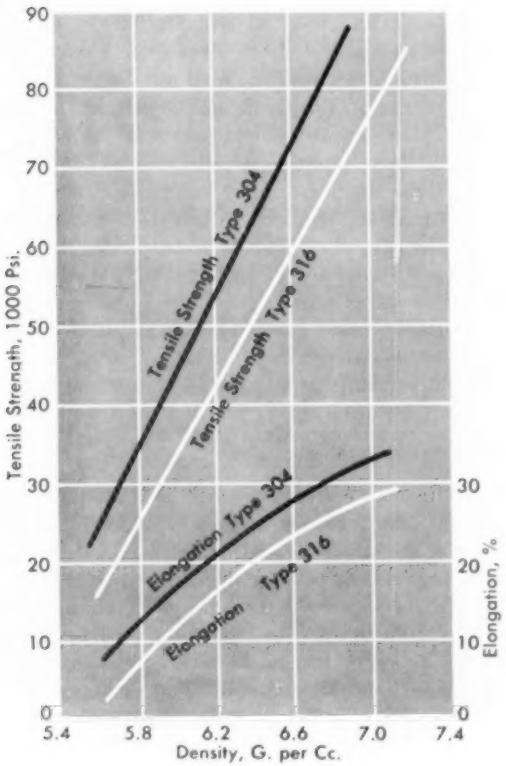


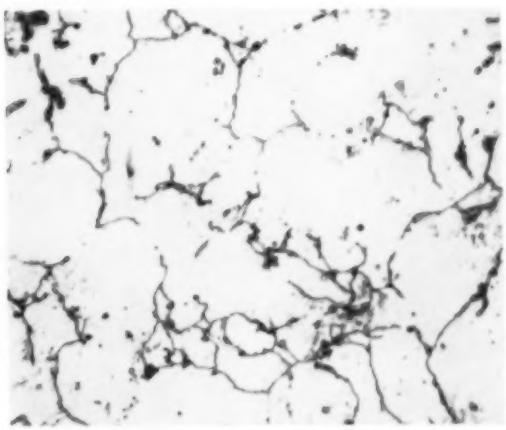
Fig. 6—How Density of Compacts Made From Types 304 and 316 Stainless Steel Powder Affects Tensile Strength and Elongation



In addition to good ductility, another outstanding feature of structural parts from stainless steel powder is virtual elimination of the tendency to seize or gall, even when run against a mating part of the same composition. We believe this nongalling property is associated with the residual porosity. In one instance, use of a sintered Type 316 sleeve bearing in a nitric acid pump against a Type 316 shaft eliminated a troublesome maintenance problem.

Besides Types 304 and 316, many special stainless powders are used for structural parts. These

Fig. 7—Microstructure of Compact Made From Type 304 Stainless Steel Powder at 75% Theoretical Density. Etched in mixed acids in glycerol, 500 ×



include A.I.S.I. Types 431, 347, 309 and 310 stainless steel as well as alloys developed for extreme corrosion and oxidation resistance such as 80% Ni, 20% Cr; 70% Ni, 30% Cu; and 75% Ni, 15% Cr, 10% Fe combinations.

Electrical Applications

Prealloyed nickel-iron and silicon iron powders are used to make electrical parts. Figure 9 shows two pole pieces made from prealloyed 50% Ni-Fe powder. They illustrate the type of part which powder metallurgy can produce with physical and electrical properties needed at a cost saving. In this instance, electrical properties required were obtained at cost savings of nearly 50% over machining. Mixtures of nickel and iron powder did not provide the necessary permeability.

Porous Metal Filters

Another important area of application for prealloyed powders is porous metal filters. Here, as noted before, Types 304 and 316 fill most specifications, but other stainless grades such as Types 321, 347 and 310 are available for more severe conditions. Where resistance to both corrosion and oxidation is required, nickel and cobalt-base high-temperature alloy powders can be employed. Porous powder parts must be compatible with the wrought sheet structures used to house them. Powders compatible with Monel, Inconel, Nichrome V, Inconel "X", Hastelloy B, Vitallium, Carpenter 20 and Stellite 31 alloys are now available.

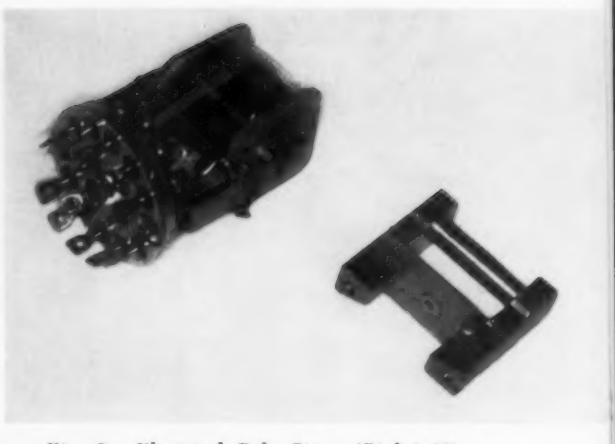


Fig. 9 – Electrical Pole Piece (Right) Was Made From Prealloyed 50% Ni-Fe Powder. Assembled relay is on left. Cost saving was 50% over machining. (Courtesy American Sinterings Div., Engineered Plastics, Inc.)

Fig. 8 – Structural Parts Made From Prealloyed Stainless Steel and Special Alloy Powders. (Courtesy Keystone Carbon Co.)

Sintered filters are produced for a wide range of requirements for the chemical, petroleum, nuclear, pharmaceutical and aviation industries. Some of these applications require pore openings as small as 0.2 micron, but the usual range is 4 to 165 microns. Sintered filters do a variety of jobs: Particles are removed from plating baths; catalyst particles are filtered from the gas streams in petroleum cracking; gases are selectively removed from other gases with filters plated with suitable catalysts; gases are mixed with other gases or liquids; or liquids are mixed together with other liquids.

Fabrication Methods

Porous metal filters are made by loose powder sintering, by extrusion and sintering, or by light pressing to the desired density, followed by sintering. Loose powder sintering involves passing a sheet of powder through a special furnace. Sheets up to 18 by 48 in. of sintered porous metal are produced by this method. These sheets can be blanked and formed readily into components for final assembly by welding.

Figure 10 shows a filter with a large area

Fig. 10 – Porous Filter Plate 4½ Ft. Diameter Made from Sintered Type 316 Stainless Powder. (Courtesy Micro Metallic Corp.)

Fig. 11 – Welding Was Used in Fabricating Representative Filters From Sintered Porous Sheet. (Courtesy Cuno Engineering Corp.)

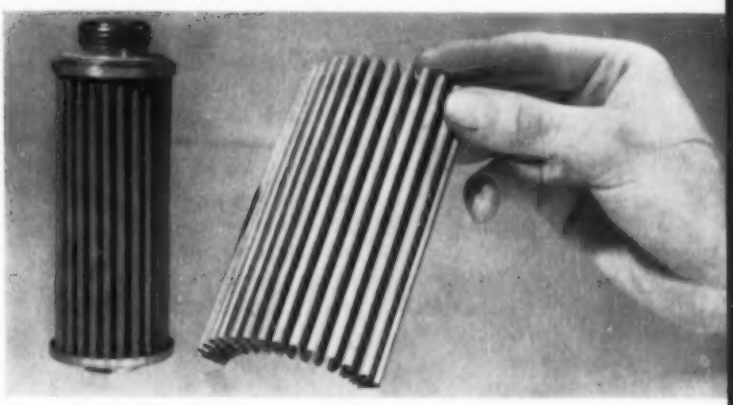


Fig. 12 – Filter Element and Finished Filter Produced From Corrugated Thin-Walled Sheet Made From Type 347 Prealloyed Stainless Powder. (Courtesy Purolator Products, Inc.)

fabricated from Type 316 porous stainless sheet. The plate – 4½ ft. in diameter – is used in a Nutch-type filter to separate penicillin crystals from mother liquor. Designed to withstand a pressure differential of 30 psi., the average pore opening of the sheet is 35 microns. Porous stainless steel was selected for this critical job for these reasons: (*a*) strength of the material; (*b*) quality of filtration obtained; (*c*) easy sterilization; (*d*) no contamination of product from linting and spalling. Figures 11 and 12 show other filters made from porous stainless sheet.

With the extrusion technique, fairly complicated filter contours can be produced which are sintered in the same manner as molded structural parts. These sintered filter shapes are welded or sinter brazed into a cartridge. In the press and sinter method, light pressing (just sufficient to permit careful handling) is employed, followed by sintering.

In all three methods of fabrication, the object is to provide 50 to 60% porosity with sufficient strength and ductility to withstand operating conditions. Filters range from a thickness of 0.015 in. up and can be designed to perform almost any filtration function. These features of porous metal filters should be noted:

- Tensile strength of the sintered filter is as much as 20,000 psi. with 5 to 10% elongation.
- In use, they will withstand pressure differentials ranging from that of a commercial vacuum to 6000 psi.
- Reverse flushing or nitric acid solutions can be used for cleaning while in service.
- They can be designed for service from –420 to 1500° F.
- There is no media migration in service.
- They provide a large filter area in a small volume.

More Fabricating Facilities

Although prealloyed powders have been commercially available since 1949, their growth has not paralleled that of iron powder. One reason has been the lack of special facilities for sintering stainless steel. Lacking sintering furnaces capable of operation at 2200° F. in a highly reducing atmosphere, most fabricators naturally stayed with production where processing was less critical. However, in the last few years, many fabricators have added equipment for making parts from stainless and specialized powders.

The relatively small amount of structural parts requiring the special properties offered by prealloyed powders has also retarded interest in developing applications. Although the metal powder process is a volume production technique, one fabricator states that as few as 10,000 pieces per year is an acceptable volume for general consideration. Sometimes even shorter runs are profitable especially where the design is complex. Each part represents an appreciable saving because of the generally higher material value and the high scrap saving.

Prices of most prealloyed powders have remained fairly high because of low volume production. However, increased consumption of certain grades of standard stainless powders has permitted a gradual reduction in prices so that cost to user is now within the framework of prices for wrought stainless steels. To encourage use of prealloyed powders, stocks of standard Types 304 and 316 stainless and 4630-A alloy steel powders are maintained for quick delivery of production lots. We also maintain small quantities of the less popular special powders. Experimental lots of special prealloyed powders can be made in quantities of 5 to 15 lb. depending on the mesh size desired. Atomizing conditions can be varied to bring out physical properties needed for specific applications.

Future Prospects Are Bright

We believe the years ahead will see increased use of prealloyed powders of all types. How soon this comes about will depend not only on the growth in production parts, such as were illustrated in this article, but also on new fabrication methods – direct rolling of powder into thin sheet, slip casting and explosive forming.

Direct rolling of metal powders is already a commercial method for thin-gage copper sheet.* In the nuclear field, powder metallurgy has been employed for small-scale production of stainless steel-uranium oxide fuel elements. Control rods composed of stainless steel-boron combinations have also been produced. Powder rolling, followed by sintering, then cold rolling the sheet produced, is the basic process used.

Other Fabrication Methods

Slip casting is a promising method for fabricating a wide range of parts. A slip which contains the metal powders is prepared. This is cast in a plaster of paris mold and subsequently sintered. This technique (see *Metal Progress*, May, 1958, p. 100) forms large or intricate shapes impossible to press. Bottle shapes, turbine buckets, intricate tools are some of the products visualized here.

Explosive forming or high-energy impact forming is another potential method for making shapes and large parts that can't be made any other way. Here, a shock wave passes through the powder and compacts the particles before they can resist deformation. High-density green compacts can be produced from relatively incompressible powders. The use of explosive forming to make production tools from toolsteel powders is a distinct possibility.

Dispersed Particles

Wider application of the hard particle or dispersoid technique to new materials as a means of improving strength at elevated temperature looks promising. Structural shapes are potentially capable of great increases in operating temperature or service life when produced from prealloyed powder with controlled oxide content or added particles for dispersoid hardening.

Fabrication of silver-indium-cadmium alloy powders with controlled amounts of oxidation into nuclear control rods has been done commercially. Their tensile and creep strengths exceed those possible with the wrought alloy.† Irradiation tests show no radiation damage.

Stainless steel nuts and washers may be made from powder if the cost of wrought bars and sheets continues to rise. Brass nuts and washers are now being produced by powder metallurgy at savings over blanking and cutting from wrought stock.

Powder Metallurgy Meeting

The 1959 meeting and show of the Metal Powder Industries Federation (formerly Metal Powder Association) will be held at the Sheraton-Cadillac Hotel, Detroit, April 20 to 22. Both the technical papers and show will stress new methods and ways to make parts with special properties.

*"Current Developments in the Rolling of Both Ferrous and Nonferrous Powders", by J. D. Shaw and W. V. Knopp, *Proceedings*, Metal Powder Industries Federation, Vol. 1, 1957.

†"Porous Metal Filter Media Solve Tough Operating Problems", by J. Kovacs, *Materials in Design Engineering*, January 1958.

Extruding Metal Powders

By ERIC GREGORY*

By modifying conventional extrusion methods, powders can be extruded in long bars with cross sections of varying complexity. In many instances, density is close to 100%. Still largely in the experimental stage, powder extrusion methods are used to produce materials with good elevated-temperature properties. They are also being considered for making certain atomic reactor fuel elements. (H14k)

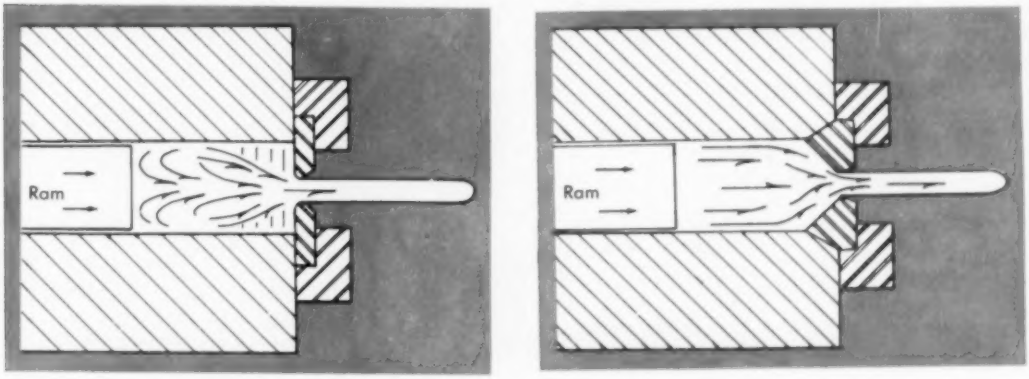
THOUGH not commercially practiced to any extent as yet, powder extrusion offers shapes and properties that cannot be obtained readily by any other method for handling powder metals. Research has solved most of the production problems. We are now engaged in a two-pronged attack on cost and properties. If cost is lowered, extruded bars can compete with regular wrought bars of similar composition and properties. In another sense, if properties are enhanced to a point that cannot be matched by any conventional materials, cost becomes less of a factor.

Powder extrusion products have two outstanding features. They can be made in long wrought shapes which have densities very close to 100%. Flats, rods and tubes have mechanical properties at least equal, and often superior, to those of similar materials produced conventionally.

These advantages, combined with many of the pluses usually cited for powder metallurgy products (extreme purity, accurately controlled compositions, uniform dispersions of nonsoluble constituents, for example), give the extrusion process great potential.

*Technical Director, Sintercast Corp. of America, Yonkers, N.Y.

Fig. 1 – Diagram Illustrating Difference Between Turbulent (Left) and Streamlined Flow (Right). Note that the conical die allows the powder to flow smoothly through the orifice



How Powders Are Extruded

In most conventional extrusions, the sharp-angled die through which the metal flows produces a shearing action, and "turbulent flow" occurs. When extruding powders, it is necessary in many instances to contain the powders within sheathing materials. Turbulence is then undesirable and an extrusion method, involving "streamlined flow", is achieved by use of a conical die. Figure 1 illustrates the difference in the flow of material during turbulent extrusion and streamlined extrusion.

The ideal method of extruding powders would be to heat them to extrusion temperature and feed them directly into the press. Many metallic powders, however, oxidize badly when heated in air, and since protective atmospheres for extrusion are not used appreciably at present, the method is restricted to certain low melting point metals. Thus, for example, magnesium and magnesium alloys are not particularly affected during heating to extrusion temperature and can be fed directly into the press. Eventually direct consolidation of even the most reactive metals by extrusion will be a reality; meanwhile, several methods are available for protecting powders prior to extrusion.

As a production process, cold extrusion is used principally for tungsten carbide. A paste is made of a powder mixture (for example, tungsten carbide and cobalt) and an organic binder. This paste is extruded through a shaped die and the binder is volatilized during subsequent sintering. While this method is technically one of powder extrusion, it does not achieve the consolidation usually desired. Actually it is merely a good way to make cold pressed powder compacts with high ratios of length to cross section.

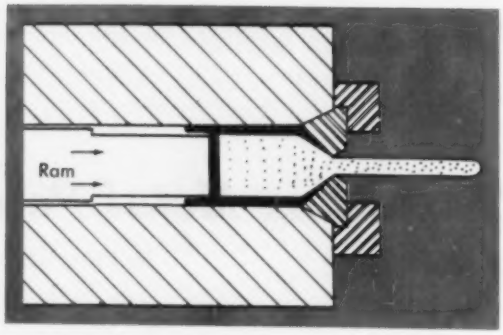


Fig. 2 – Canned Extrusion With Breakthrough. Penetrator ram forces densified powder through can and die; thus, cross sections have better dimensional accuracy. This method also eliminates an extra step since the can does not have to be removed when extrusion is finished

Cold Pressing Before Extrusion

Here, the powder is pressed into a billet, heated to extrusion temperature (in a protective atmosphere if necessary) and rapidly transferred to the press container. Before going through the die orifice, the powder is compacted in the container, and later stages are almost identical to those of solid billet extrusion. Both streamlined and turbulent flow are suitable, and the latter may be better if it permits more densification before extrusion begins.

This simple powder extrusion process has only limited application due to drawbacks such as:

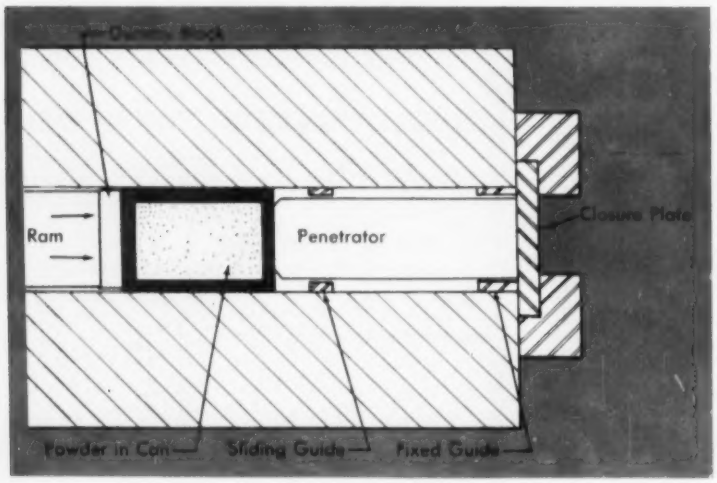
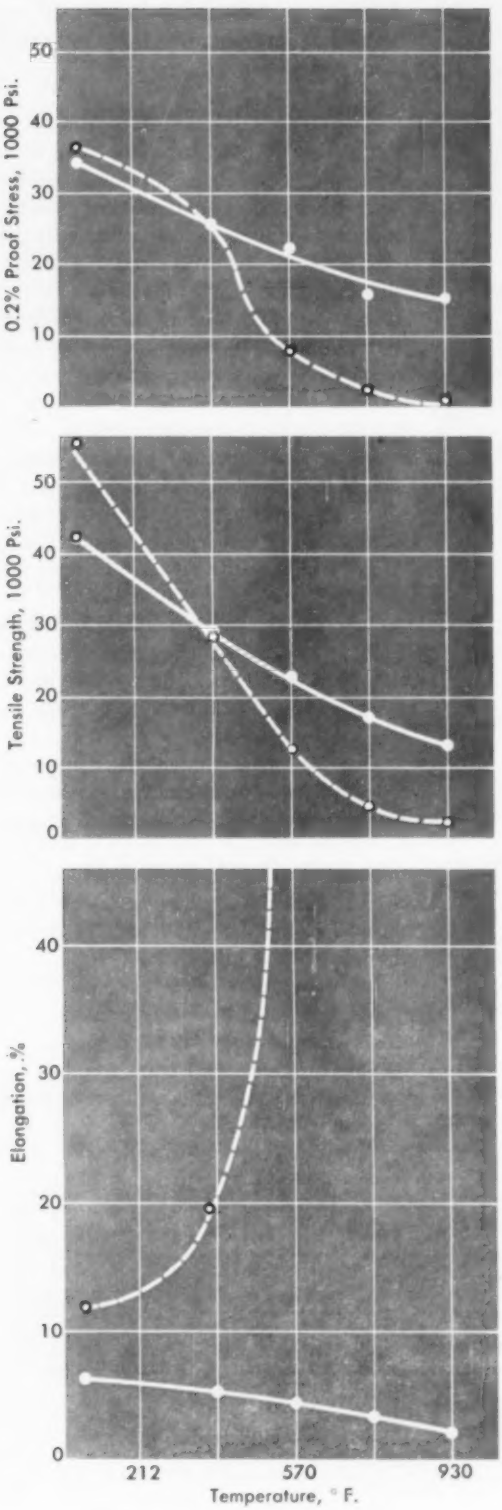


Fig. 3 – Consolidating Canned Powder. After this step, the can is removed, and the solid block of powder is extruded



1. Oxidation – The porous billet, although heated in a protective atmosphere, may be oxidized or become otherwise contaminated when transferred to the press. This is particularly true for reactive metal powders.

2. Difficulty of Homogenization – Alloying of powder combinations cannot be done easily; there is no time prior to extrusion for diffusion of the constituents. A post extrusion heat treatment would be required and this may lead to several unwanted effects.

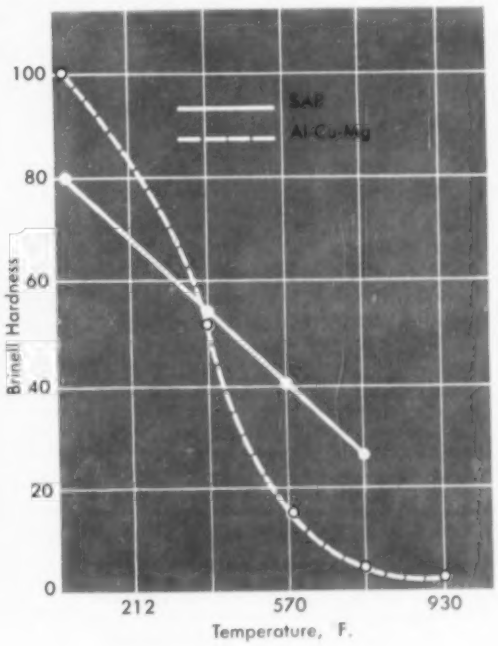
These drawbacks can be avoided if cold pressing is followed by prolonged sintering in a protective atmosphere. Homogenization is achieved, and if the operation also reduces the billet porosity, oxidation is reduced.

Hot Pressing Before Extrusion

Hot pressing, carried out in a protective atmosphere, can compress the billet up to 100% of theoretical density before transfer to the extrusion press. This reduces the danger from oxidation and gaseous contamination to a negligible amount.

However, hot pressing generally requires but a short time and may not completely homo-

Fig. 4 – Comparison Between Mechanical Properties of SAP and Heat Treated Al-Cu-Mg Alloy. Note that properties of SAP decrease gradually while those of Al-Cu-Mg drop suddenly



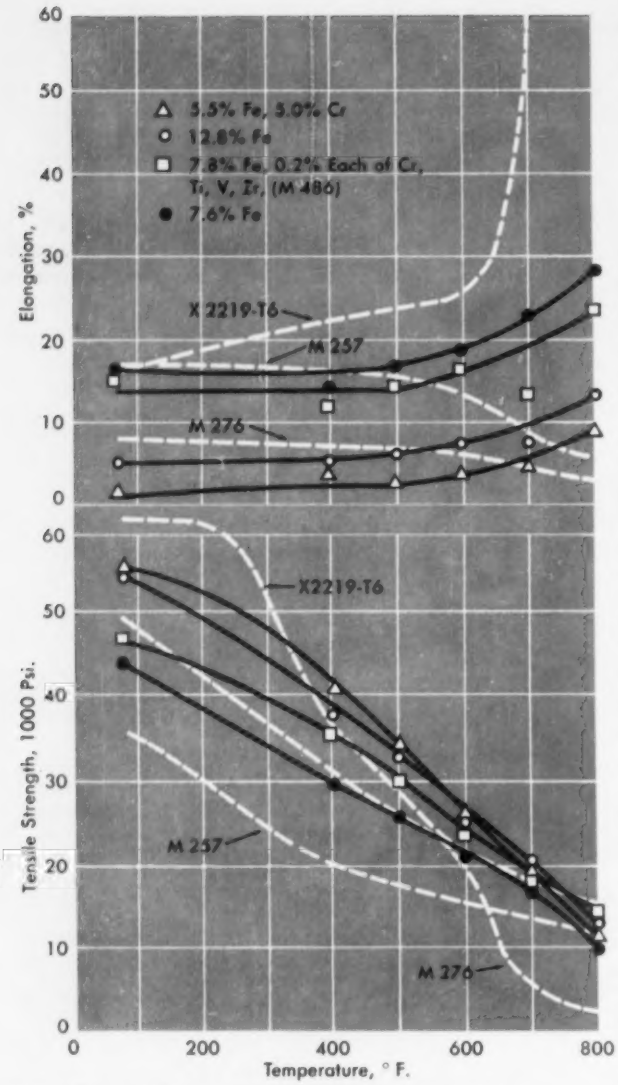


Fig. 5 – High-Temperature Properties of Extruded Rods of Atomized Alloy Powders Compared With Those of M 257, M 276 and X 2219-T 6. Specimens were held 100 hr. at temperature before testing

genize powder mixtures. Sometimes, billets are cold pressed, sintered and then hot pressed for both maximum density and homogenization.

Canning Avoids Contamination

Often it is difficult to hot press in an atmosphere which is sufficiently protective to avoid contaminating reactive metals. If this is the situation, a further modification must be used. The cold pressed and sintered billet is placed in a metal can and sealed under vacuum. Extrusion by the streamlined flow technique follows.

With this method, the material used for the can is of utmost importance. The extruder must consider physical properties of the sheathing material (relative to those of the billet) over a range of temperatures. Furthermore, compatibility of the can with the powder, furnace and working atmospheres is essential. The sheath material occasionally aids flow by reducing contact between powders and die. This technique also reduces health risks during the extrusion of toxic or radioactive powders.

Canning has drawbacks, however. Decanned material is not dimensionally accurate and there is an extra operation to remove the can. The latter is done by machining or by chemical dissolution.

A modification which reduces these drawbacks is illustrated in Fig. 2. Although canned initially, a special penetrator ram helps the material break through the sheath during extrusion. If this method is used, there is no can removal problem and dimensional accuracy of the extrusion can be maintained more easily and accurately.

For many reasons, it *(Continued on p. 150)*

Table I – Comparison of Billet and Powder Extrusions of Magnesium*

Heat Treatment	Cast Billet Extrusion (800° F., 15 Ft. per Min.)			Powder Extrusion (800° F., 100 Ft. per Min.)		
	0.1% Proof Stress	Tensile Strength	Elongation	0.1% Proof Stress	Tensile Strength	Elongation
As-extruded	10,300 psi.	27,800 psi.	9%	22,400 psi.	37,200 psi.	5%
8 hr. at 480° F.	—	—	—	22,000	37,600	8
8 hr. at 660° F.	9,200	26,700	8	—	41,000	10
24 hr. at 840° F.	11,200	21,000	4	25,800	40,100	6

*Values quoted are single determinations.

Salt bath heat treating helps put you in a better competitive situation!

The Ajax files are full of case history records such as these. Each represents a typical instance where replacement of other heat treating systems with Ajax Salt Baths have meant important cost reductions or greatly improved quality—*and usually both:*

$37,000 WAS SAVED in 8-months by an Ohio manufacturer through using an Ajax Electric Salt Bath installation for 4 different cost-cutting operations i.e. carburizing, simultaneous carburizing and brazing; brazing; and hardening.

A 350% PRODUCTION INCREASE in 45% less space with 50% less labor was achieved in carburizing bearing races in a 6-unit Ajax Electric Salt Bath installation.

A 60% COST REDUCTION in case hardening body screws was scored by a single Ajax Salt Bath no larger than your desk but handling 390 lbs. of work per hour.

AN 80% REDUCTION in finish grinding time was obtained by martempering SAE-52100 bearing races in an Ajax installation. Drawn to Rc 62-63, the races showed average out-of-round distortion of only 0.002-0.003".

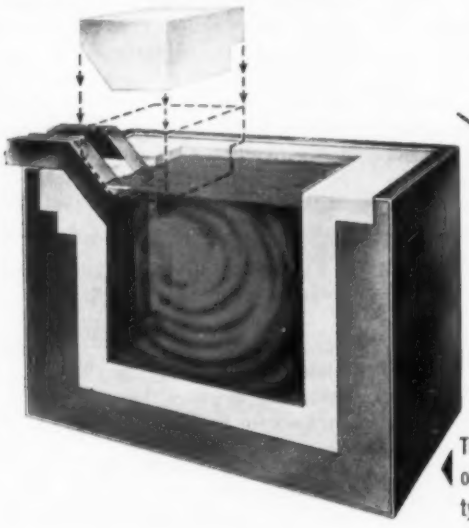
A 4 TO 5 TIME LIFE INCREASE for rock bits resulted from Ajax Salt Bath hardening which also made possible use of plain carbon rather than costly alloy steel. 480 lbs. of work per hour are handled in a bath only 36" x 11" x 36".

SIMULTANEOUS CARBURIZING AND BRAZING of a complicated motor starting assembly are done in one Ajax furnace with one heating of the work as compared to two heatings previously required.

Savings like these are vitally important—and Ajax can help you to realize them to the fullest extent.

The chief product of Ajax is applied heat treating "know how" . . . not merely the largest assortment of salt bath furnace types in the world. When you discuss heat treating matters with Ajax, you get full benefit of unmatched experience not alone in designing and selling furnaces, but in helping you utilize them to best possible advantage.

There is no obligation in having Ajax make a frank appraisal of your heat treating situation.



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Personal Mention

Hans Ernst

HANS ERNST, after a long and successful career in industry, has become a member of the faculty of the University of Cincinnati as Herman Schneider research professor in the college of engineering. His broad experience and international reputation in the field of basic and applied research fit him admirably for this chair, which honors the late Dr. Herman Schneider, long dean of the University's college of engineering.

Born and educated in Melbourne, Australia, Ernst came to the United States in 1915 and, after a number of years in research and machine development work, joined Cincinnati Milling Machine Co. in Cincinnati, Ohio, in 1926. He organized the company's research department, and for more than 30 years, as director of research, was in charge of research and development. Since his retirement in 1957, he has been a consultant for the company.

His achievements have received wide recognition; in 1950 he received the outstanding engineer award of the Technical and Scientific Societies Council of Cincinnati and in 1957 was awarded the first national research medal of the A.S.T.E.

His list of technical society memberships is a long one and includes the Engineering Society of Cincinnati over which he presided as president in 1948.

One of his major outside interests is flying – he has been piloting his own aircraft for the past 12 years.

Karl L. Fetters

KARL L. FETTERS is one of four new vice-presidents elected by the board of trustees of the Youngstown Sheet and Tube Co. in Youngstown, Ohio. Dr. Fetters' concern will be research and development.

A graduate of Carnegie Institute of Technology and Massachusetts Institute of Technology (where he received his doctorate in 1940), he has been affiliated with Youngstown Sheet and Tube intermittently for nearly 25 years. He joined the company as an openhearth metallurgist in 1936; two years later he left for M.I.T. where he spent one year as a research assistant and another as a national openhearth fellow, returning to the company as a general metallurgist. During the early war years, he was assistant professor and a staff member of the Metals Research Laboratory at Carnegie Institute of Technology, in charge of the Office of Scientific Research Development project on seamless gun tubes. He returned again to Youngstown in 1943 as special metallurgical engineer on the staff of the operating vice-president, was appointed assistant to the vice-president in charge of operations in 1950 and assistant vice-president six years later.

The technical organizations which claim his greatest interest are the American Institute of Mining, Metallurgical, and Petroleum Engineers (he is a member of its general research committee and is chairman-elect of the Iron and Steel Div.) and the American Society for Metals. He has been a member of many, many ASM committees, including the National Education Committee of which he was chairman for one year, and served as a National Trustee for two years. He was the Society's representative at the Joint Metallurgical Societies Conference in Europe in 1955 and in 1949 was chosen as the first lecturer for the Mahoning Valley Chapter Marcus A. Grossman Lecture.

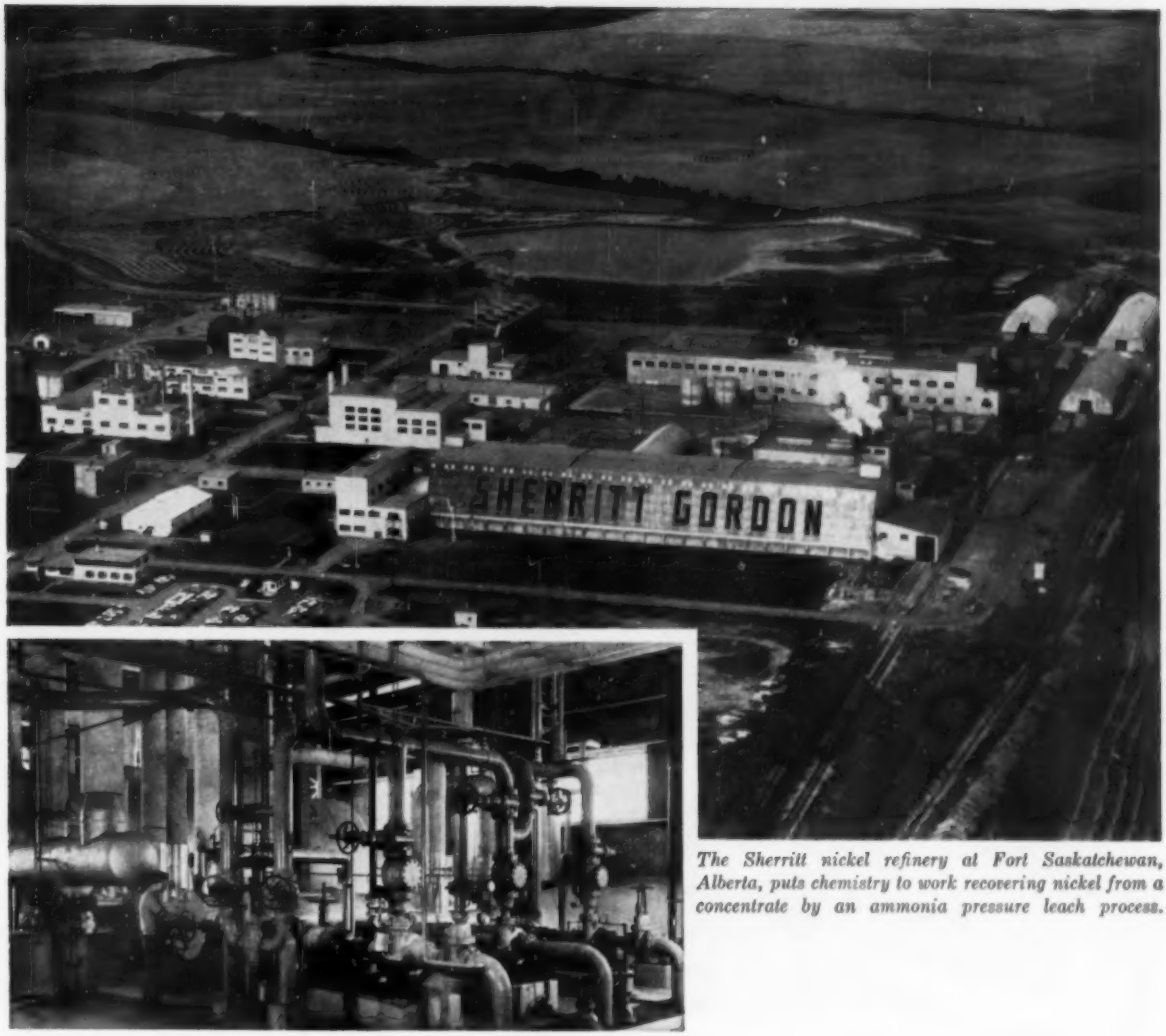
Ralph A. Smith has been appointed chief materials and test engineer for Fulton Sylphon Div., Robertshaw-Fulton Controls Co., in Knoxville, Tenn., where he will direct the activities of the division's engineering physical laboratory and its chemical and metallurgical laboratories and will be in charge of design and development work on mechanical sealing elements.

William P. Henkel has been named district manager of Dayton, Ohio, for Latrobe Steel Co., Latrobe, Pa. He has been a Dayton sales staff member for five years, assigned to southern Ohio and Kentucky and operating from Cincinnati.

Leonard R. Mehlman has joined the headquarters organization as staff engineer assigned to the Castings Design Project which is preparing a manual for the design of aircraft castings for the Air Materiel Command, U.S. Air Forces. Until recently, Mr. Mehlman was chief engineer of Prestole Corp., Toledo, Ohio. He started in the foundry industry as a patternmaker, became a castings designer with Jack & Heintz during the war, and subsequently was employed by Tinnerman Products Inc. of Cleveland as a product designer and later chief standards engineer.

Frederick C. Ochsner has been named a product manager by Metals & Controls Corp., General Plate Div., in Attleboro, Mass. Prior to joining the company in 1950 as a field sales engineer, he was a sales engineer for H. A. Wilson Co.

Norman F. Spooner has been promoted from supervisor to manager of research and development for Hoskins Mfg. Co., Detroit. A graduate of the University of Michigan, Mr. Spooner has been with Hoskins for the past 10 years.



The Sherritt nickel refinery at Fort Saskatchewan, Alberta, puts chemistry to work recovering nickel from a concentrate by an ammonia pressure leach process.

nickel refining

in a new era of hydrometallurgy

Sherritt's nickel refinery represents a most significant advance in the art of hydrometallurgy. Conventional smelter/electrolytic refinery techniques are replaced by a more efficient and more economical chemical process. The process, developed during four years of intensive pilot plant studies, is unique in its use of low pressure, low temperature ammonia leaching, followed by hydrogen reduction of metallic nickel from the aqueous solution. Three hundred and forty tons of nickel concentrate are processed each day with a yield of 35 tons of nickel, 10 tons of copper residue, and 1000 pounds of cobalt.

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FOOTE MINERAL COMPANY is the exclusive sales agent for Sherritt nickel and cobalt in the United States and Canada. For product literature, prices, and delivery information, contact the Foote Mineral Company, 424S Eighteen West Chelten Building, Philadelphia 44, Pa.

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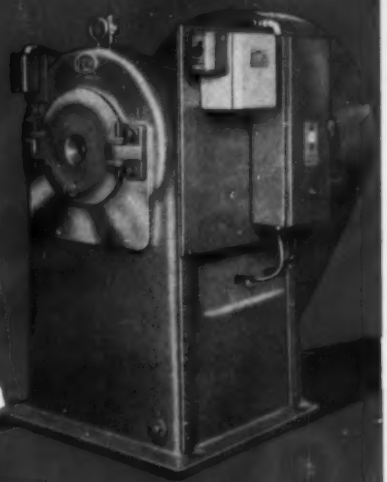

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**Tooling and electrical equipment not included.*

FENN *Sets the Pace* IN ROTARY SWAGING

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Personals . . .

R. J. Bullock has left Capital Metal Industries in Toronto, Ont., to accept a post as salesman for the American Brass Co. in Waterbury, Conn.

Jesse B. Burton has retired as chief design engineer of the press department of the Waterbury Farrel Foundry & Machine Co., Waterbury, Conn., and will spend this summer traveling through Europe.

D. L. Henry, formerly with General Electric Co. in Evendale, Ohio, as a materials development engineer, is now a senior research engineer on advanced reactor materials at North American Aviation's Atomic International Div. in Canoga Park, Calif.

Norman P. Goss, a Cleveland consultant, has been issued U. S. Patent No. 2,866,703 which relates to a method for removing carbon, sulphur, silicon and other impurities from large quantities of molten iron.

Peter C. Prior has been elected president of Smith-Armstrong Forge Inc., Cleveland, Ohio.

O. C. Anderson has been appointed manager of quality control for the Brackenridge, Pa., works of Allegheny Ludlum Steel Corp. His former position of works metallurgist has been filled by **William Wells, Jr.**, supervising metallurgist, works metallurgical laboratory.

Edgar C. Bain was awarded the Ambrose Monell Medal "for distinguished achievement in mineral technology" by Columbia University, adding another to the long list of honors he has received during his metallurgical career. Now retired, Dr. Bain was assistant executive vice-president, operations, in charge of the research and technology division, for U.S. Steel Corp. until 1957.

Victor E. Demski and **William J. McChesney, Jr.**, have received appointments as supervising metallurgists in the quality control department of the Leechburg Works of Allegheny Ludlum Steel Corp., Pittsburgh. Mr. Demski will specialize in stainless, carbon and toolsteels, and Mr. McChesney will supervise quality control procedures concerning silicon steel production.

Uses donut-shaped Inconel pot for fast heat-up and long life...

New automatic induction salt pot furnace is small enough to fit any shop

Lindberg Engineering makes this one... and it's unique for versatility, capacity and appearance. Looks more like an indexing-type machine tool than a neutral salts pot. Operates much the same way, too.

With induction heating . . . rather than electrodes . . . unit may be shut down overnight. Takes only 1½ hours next A.M. to come to 1700°F.

Inconel alloy insures reliable operation

For the unique "donut" design of the pot Lindberg Engineering Company selected Inconel* nickel chromium alloy. This alloy has an outstanding record for resistance to attack by neutral salts or heat in and above this range. It also withstands oxidation and the many problems associated with cyclic heating and cooling.

These problems could be serious in a structure like this which "unrolled" would approximate ten feet in length. In huge-surface equipment, Inconel alloy has an enviable record for retaining original strength and configuration despite thermal stresses.

Inconel alloy lends itself well, too, to the type of fabrication that is essential to this unusual design. Sheet is readily formed and welds are both easy to make and sound.

Your Inco distributor will be glad to give you full information on Inconel alloy. Just look under "Nickel" in the yellow pages of your phone book for his name and address.

*Registered trademark

The International Nickel Company, Inc.
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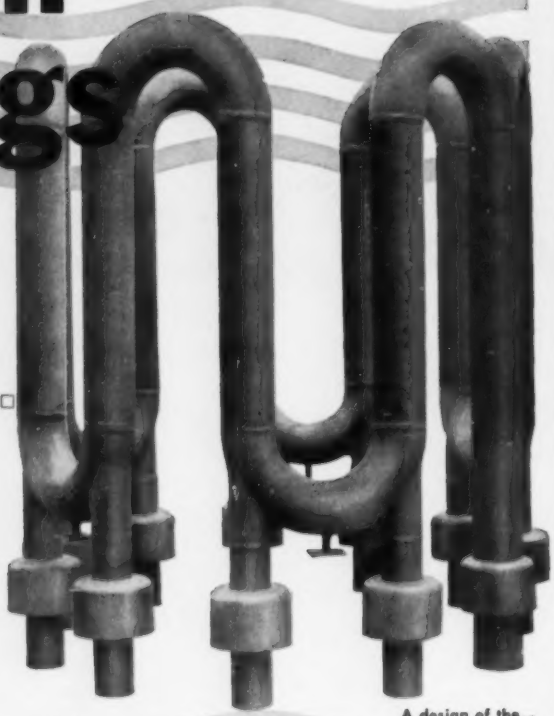

A design of the A. F. Holden Co., Detroit, Mich.

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Personals . . .

Dudley S. Engleby, a 1958 graduate of the school of metallurgical engineering, Virginia Polytechnical Institute, is currently employed as assistant plant metallurgist with the pneumatic tool division of Ingersoll-Rand Co., Athens, Pa.

John W. Weyers has been appointed manager of the rod fuel operations in the manufacturing section of the atomic power equipment department, General Electric Co., San Jose, Calif.

Raymond C. Angell received a bachelor of science degree from the University of Pittsburgh in February and is now working as a student engineer at the Beaver Falls, Pa., plant of Babcock and Wilcox.

H. R. McPherson has transferred from the communications division of the Ramo-Wooldridge Corp. to Space Technology Laboratories Inc., Los Angeles, as materials and process engineer.

Ralph J. Kotfila, formerly with Cruicible Steel Co. of America's titanium division, has joined the solid rocket division of Aerojet-General Co., Sacrameto, Calif., as production engineer in the producibility engineering department.

Willard M. Garcia has joined General Electric Co. as a technical engineer in the metallurgical engineering section, Flight Propulsion Laboratory Dept., Aircraft Gas Turbine Div., in Cincinnati, Ohio.

John A. VanWestenburg has been on the faculty of the Michigan College of Mining and Technology for the past two years as an assistant professor of metallurgy. He was formerly associated with Dow Chemical Corp., Midland, Mich.

R. J. Johnson recently transferred from Pittsburgh to the New York office of International Nickel Co. where he will be engaged in alloy development.

Don F. Atkins recently accepted a post as research engineer with Atomics International, a division of General Dynamics Corp., Canoga Park, Calif. He was formerly with the department of metallurgical research, Kaiser Aluminum and Chemical Corp., Spokane, Wash.

The refractory aluminum can't lick!

...CRYSTOLON* Silicon Carbide

Impact on a charging hearth . . . a surge of molten metal into a trough . . . attack by corrosive alloys, fluxes and slags . . . Norton CRYSTOLON Refractories stand up to *all* these rigors of aluminum melting and transfer operations. Their exceptional stamina and stability not only protect purity throughout critical processing but also sharply reduce refractory maintenance.

Small wonder. CRYSTOLON Refractories are the most resistant to corrosion and erosion of all known refractories — and they offer outstanding mechanical strength and the highest resistance to thermal shock.

Ideal for use at all key melting, holding and transfer points, CRYSTOLON Refractories are specifically recommended for reverberatory and induction type furnaces. On the melting hearth, in the hot wall, in the holding hearth, and in many other critical areas, they assure longer refractory life . . . cleaner metal, free from refractory inclusions. What's more, CRYSTOLON Refractories are not wet under these corrosive conditions. Refractory surfaces stay clean longer . . . last longer.

Use these versatile refractories wherever aluminum could cause costly trouble . . . wherever contamination is a threat: in melting areas, launders, spouts and simple valves . . . for tap blocks and stopper rods. Take full advantage of today's high purity pig . . . *protect* purity during *your* operations. Reduce your reject losses with Norton CRYSTOLON Refractories. Several types are available to meet your precise requirements: oxide-bonded CRYSTOLON "G"; nitride-bonded CRYSTOLON "N" and recrystallized CRYSTOLON "R" Silicon Carbide. For complete details, write NORTON COMPANY, Refractories Division, 323 New Bond Street, Worcester 6, Mass.

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The improved particle shape now achieved in Vasco Prealloyed Metal Powders results in better moldability and increased green strength . . . advances that join with the inherent superiority of *prealloyed* powder performance to create the most versatile, easy-to-use range of high-strength metal powder grades available today.

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Vanadium-Alloys Steel Company

Powder Metallurgy Department

LATROBE, PENNSYLVANIA

Personals . . .

Edwin D. Bash has been named asistant to the works manager at the West Leechburg Works of Allegheny Ludlum Steel Corp. Formerly supervising metallurgist, he will now specialize in customer contact work.

W. H. Steurer, previously chief of materials research at the Army Ballistic Missile Agency, Redstone Arsenal, Ala., has accepted a post as chief of engineering materials at Convair, a division of General Dynamics Corp.

I. S. Hirschhorn has been promoted from general manager to vice-president and general manager of New Process Metals, Inc., Newark, N.J., a subsidary of Ronson Corp. He joined New Process Metals in 1949 as technical director and became general manager in 1950.

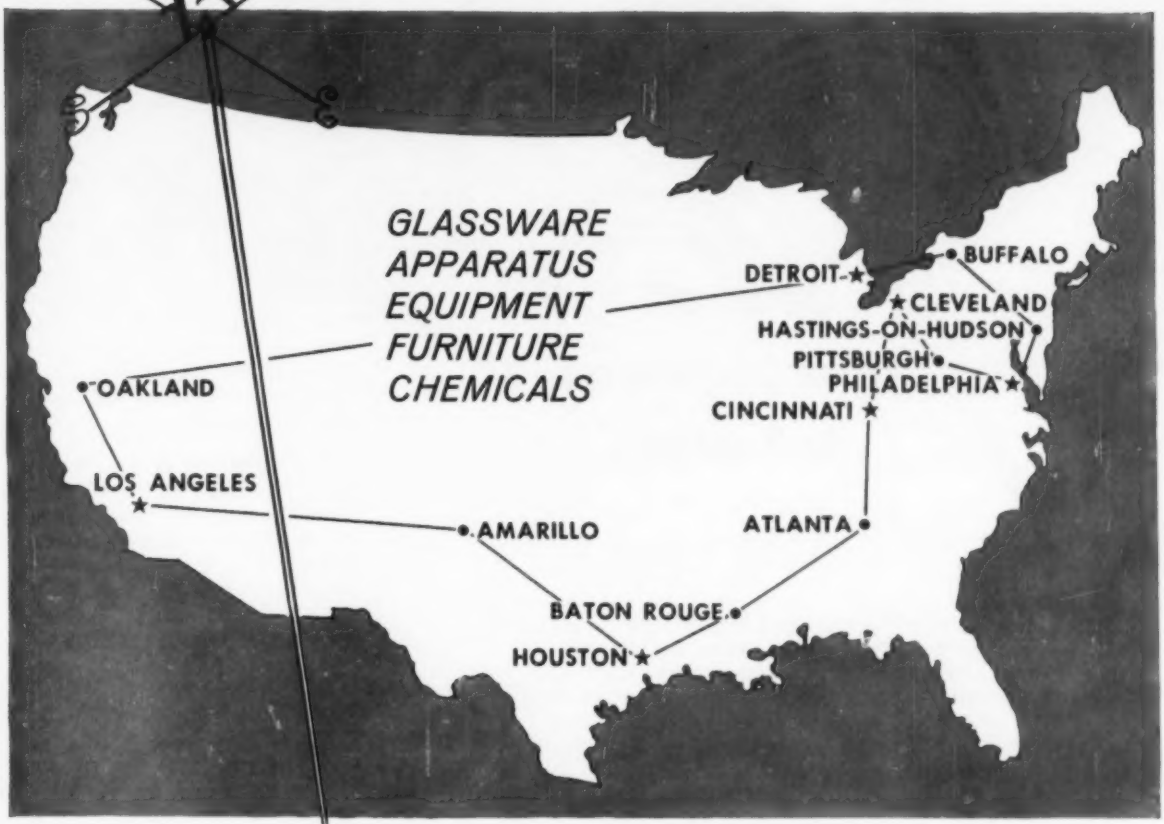
H. W. Lownie, Jr., research metallurgist at Battelle Memorial Institute, Columbus, Ohio, has been voted the John H. Whiting Medal for 1959 by the American Foundrymen's Society for "outstanding contributions to the Society and metallurgical progress". Chief of Battelle's process metallurgy research division, Mr. Lownie was cited for his role in gray cast-iron research.

Joseph I. Doherty has been named manager of the Windsor, Conn., office and warehouse of Whitehead Metals, Inc. Since joining Whitehead in 1927, he has served as field engineer and most recently as assistant manager of the Windsor facility.

Edward A. Loria has been appointed development manager, high-temperature and corrosion resistant alloys, for Climax Molybdenum Co., a division of American Metal Climax, Inc. Before joining Climax, he was product metallurgical engineer for Crucible Steel Co. of America.

Arthur B. Backensto, Jr., has been appointed research metallurgist of the Alan Wood Steel Co., Conshohocken, Pa., where he will head a research program directed toward increased usage of iron powder. Before joining Alan Wood, Dr. Backensto was associated with Bendix Aviation Corp., in Troy, N.Y.

Harshaw Scientific Offers Laboratories National Service on a Local Basis



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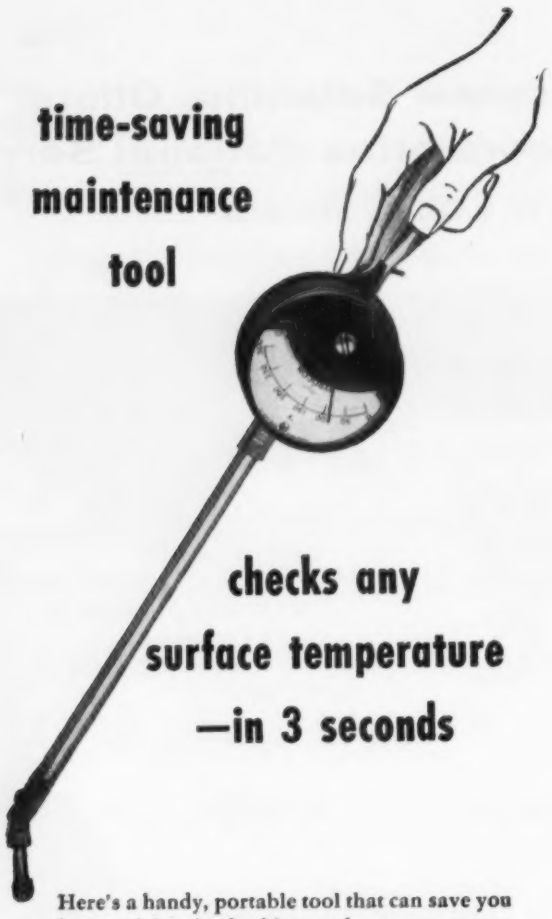

time-saving maintenance tool

checks any surface temperature —in 3 seconds

Here's a handy, portable tool that can save you hours of time in checking surface temperatures of steam traps, water lines, electric motors, bearings, etc.

The Alnor Pyrocon gives instant, accurate temperature readings of any surface: metallic or non-metallic, flat, curved—even revolving surfaces. It's a well-balanced instrument mounted in a sturdy case for protection against the usual hazards of on-the-job service. Jeweled movement is also heavy-duty, shock-resistant type that will withstand hard and continuous use...performing with laboratory accuracy.

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Personals . . .

Richard Lee Jones, after receiving a doctorate in metallurgical engineering from the University of Michigan last August, took a position with the engineering materials section of Convair Astronautics, a division of General Dynamics Corp., in San Diego, Calif., as a senior research engineer.

Frank St. Germain has been assigned to the applied studies department of the Polaris Development Project at Aerojet-General Corp., Sacramento, Calif., as a specialist on high-temperature materials.

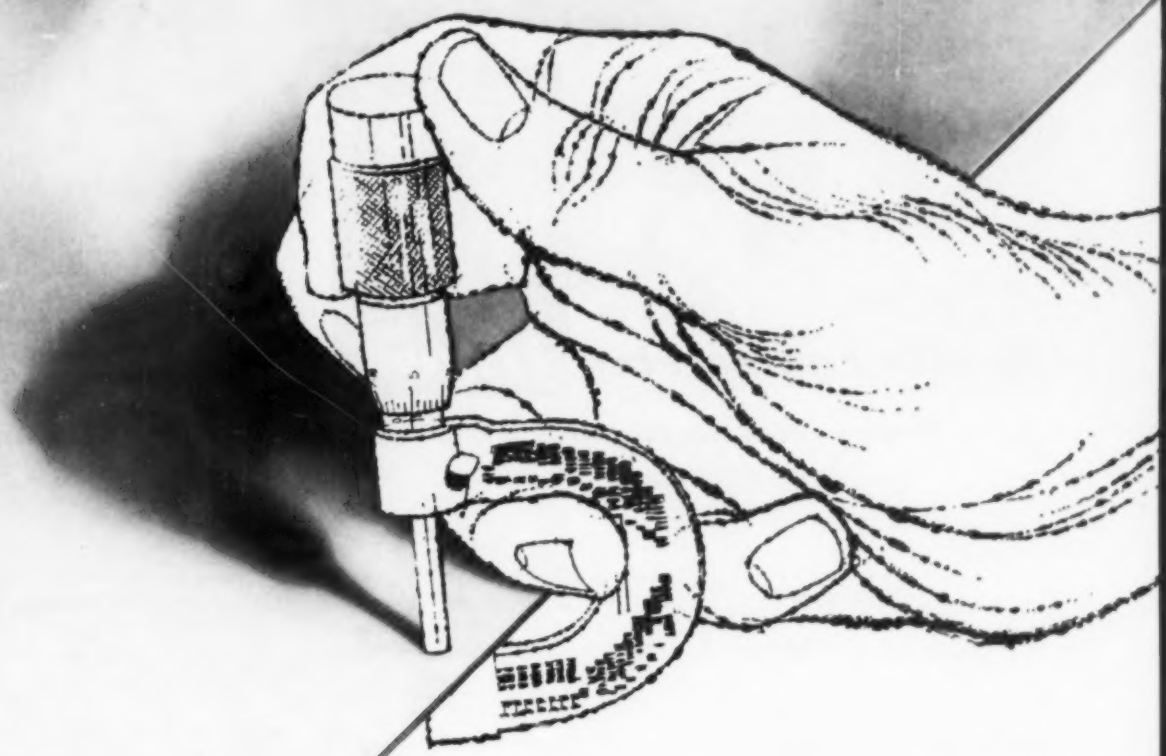
Anthony G. Maletta, a former senior materials application engineer for Wright Aeronautical Div. of Curtiss-Wright Corp., was recently elected vice-president of Fact Technical Service, Inc., Rochester, N.Y., where he has charge of the soils, construction materials and metallurgical testing laboratory.

L. W. Horvath has been appointed manager of the newly established industrial furnace division of Diversey Engineering Co., Franklin Park, Ill.; offices and manufacturing facilities of the division will be located at Diversey's new plant in Huntsville, Ala. He was formerly associated with Loftus Engineering Corp., Pittsburgh, in charge of the heat treating furnace and oven division in Chicago.

A. L. Ascik has been promoted from general superintendent of the Calvert City, Ky., plant of Pittsburgh Metallurgical Co., Inc., to technical director with headquarters in the company's Niagara Falls, N.Y., home office.

R. W. Wilson, formerly Chicago district manager of the Electro Metallurgical Co. division of Union Carbide Corp., has joined American Hoist & Derrick Co., St. Paul, Minn., as assistant manager of the foundry division.

Stuart B. Mathews has retired from Edgcomb Steel Co., Philadelphia, after 25 years spent in various sales capacities. For many years he was assigned to the Philadelphia and middle Atlantic states, and for the past three years covered the Florida area for Edgcomb's Charlotte, N. C., warehouse.



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INSIDE—Microstructure control through processing techniques developed by J&L offers important advantages. For example, improved stamping, forming and drawing qualities; uniform response to heat treatment; reduction of heat treating distortion. This product is available in various internal structures and is also available in all hardness ranges—dead soft, intermediate and spring tempers.

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Weldability of High-Strength Steel

Digest of "The Weld-Heat-Affected Zone," by Ernest F. Nippes, Rensselaer Polytechnic Institute, Troy, N.Y., 1958 Adams Lecture of the American Welding Society.

THE ADAMS LECTURER for 1958 reviewed continuous work done largely under his direction which started as far back as 1943. Its general aim has been to establish means whereby the thermal history of any region in the metal immediately alongside a fusion weld could be predicted, given the thickness of the plate being welded, its preheat (if any), its chemical composition, and the heat input of the welding current. Since a fast heating and cooling cycle of this sort would have a predictable effect on all the physical properties of annealed steel or other alloy, welding conditions for a successful joint in a given piece of metal should be predictable.

Obviously this is a large order. The lecturer cited no less than 14 major contributions to the literature coming directly from the investigations at Rensselaer Polytechnic Institute. His long lecture was a brief summary. This short review can be but a digest of the summary.

In the first stage of the work, numerous thermocouple junctions were embedded at strategic places alongside a V-notch in ½-in. steel plate, and heating and cooling curves recorded as weld-beads were laid down under standard conditions of voltage, amperage and arc travel.

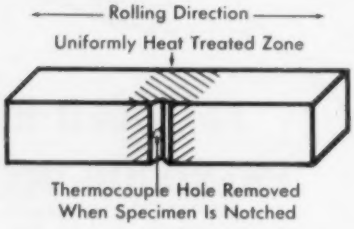
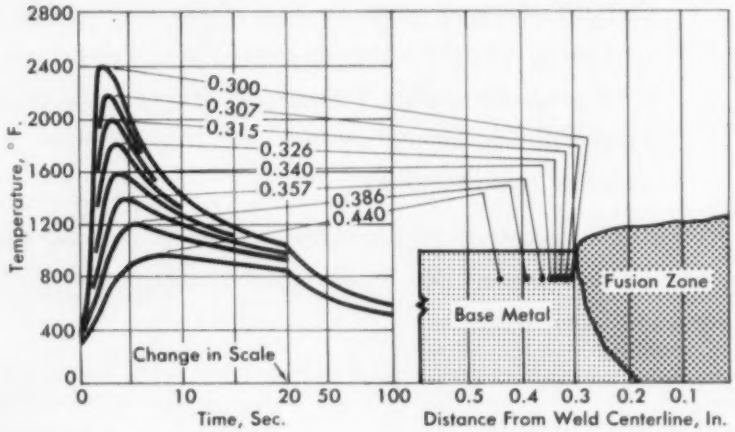


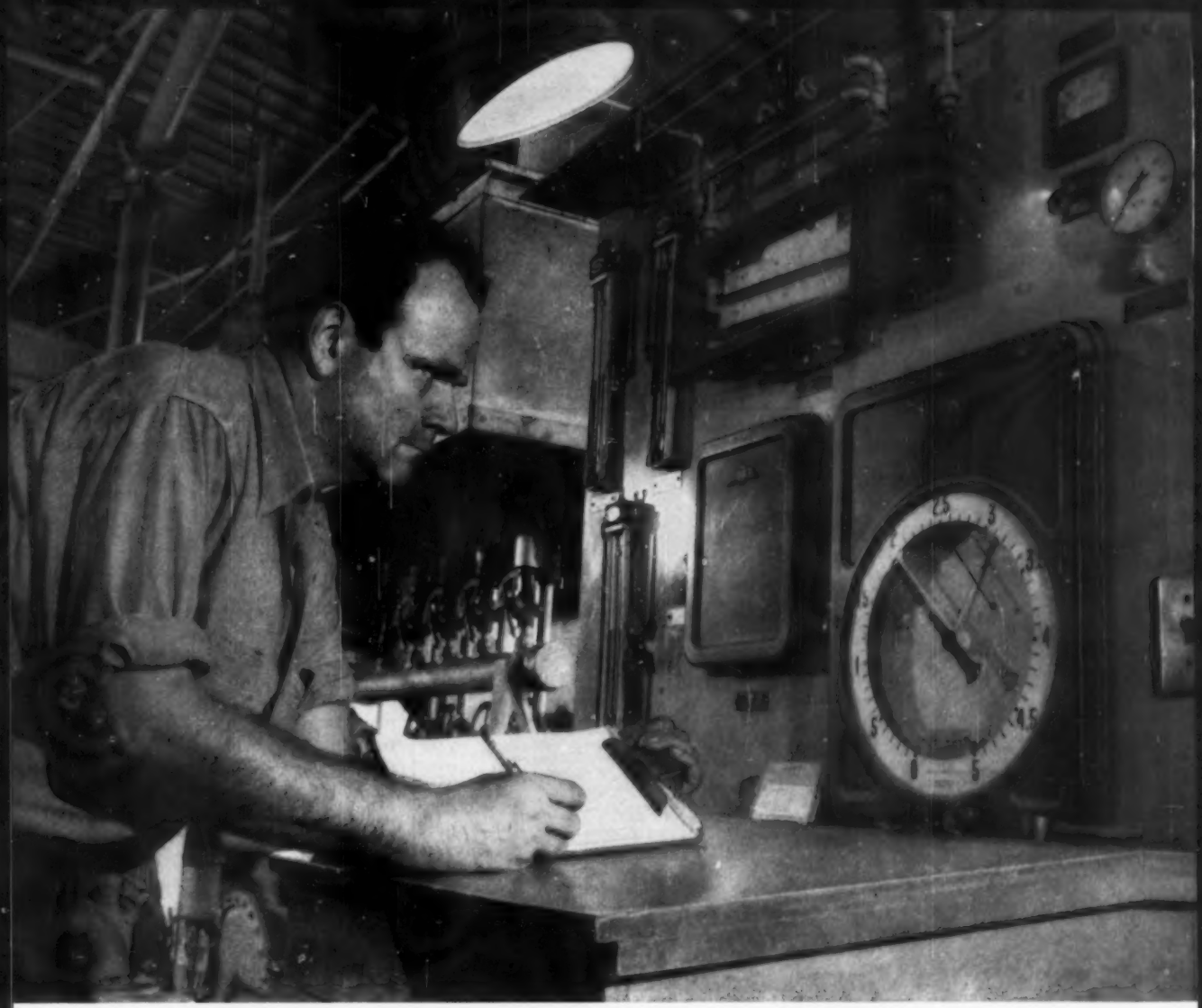
Fig. 1 – Standard Charpy Impact Specimen Prepared by Subjecting Its Entire Cross Section to the Heating and Cooling Cycle Actually Experienced by a Chosen Spot Alongside an Arc Weld

The samples were then sectioned in various ways and the resulting microstructures photographed. Several distinct zones were immediately apparent: *(a)* a region of grain growth; *(b)* a region of grain refinement; *(c)* spheroidization. Could this conglomeration of effects be used to predict the resultant properties?

It turned out that the heating and cooling curves could lead to quantitative estimates if the hardenability and transformation characteristics of the metal were known. Hardenability, of course, has long been measured by the standard Jominy test; data on transformation during continuous cooling are being accumulated steadily. Professor Nippes cited one such problem:

Fig. 2 – In an Investigation of Weldability of "T-1" (High-Strength) Plate) Charpy Impact Specimens Were Heated and Cooled at Cycles Characteristic of Thermal History of the Metal at Indicated Positions





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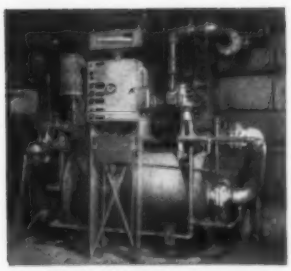

Two Kemp MIHE Inert Generators supply oxygen-free atmosphere for annealing copper wire at Belden Mfg. Co., Chicago. Belden gets an even, dependable supply of inerts at low cost and with minimum maintenance and attention.

Tested . . . and proved! Factory tested with rigid component checks, field tested by Kemp engineers at installation, and time tested by years of actual use. Proved that Kemp Inert Gas Generators are built to last, built to produce, built to be accurate.

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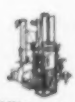


Nitrogen Generators

Orlad Dryers

Weldability . . .

Weld 1-in. plate of NE 8620* steel so there would be no hard and brittle martensite in the zone alongside the weld and a maximum hardness of Vickers 280. To avoid primary martensite, maximum cooling rates of 12° F. per sec. at 800° F. were indicated, and this would be achieved in plate preheated to 400° F. with an arc having an energy input of 56,000 joules per in. In nonpreheated plate the arc could have double the energy. That was the prediction. Joints so made in the laboratory had maximum hardness of 289 and 283, respectively.

The next milestone in this extensive research was the construction of apparatus wherein the exact heating and cooling cycles of any chosen region alongside the weld could be exactly duplicated in the entire cross section of a standard test piece for impact, tension, fatigue or any other mechanical property. This apparatus clamps the specimen between terminals so a closely controlled current heats it by its own electrical resistance. The signal from a thermocouple attached to the specimen is balanced against the signal from a potentiometer controlled by a moving cam cut from sheet metal and represents the desired heating and cooling curve. Any difference between these two signals increases (or decreases, as the case may be) the current going through the specimen. Figure 1 shows how a standard Charpy impact specimen would be so prepared; the thermocouple controls temperature accurately at the root of the notch, but the whole hatched area has been similarly treated. Thus the impact strength and microstructure of any small spot in an actual weld can be determined. (A later refinement has been to include this heat treating equipment in high-speed testing machines so properties *at temperature* could be determined.)

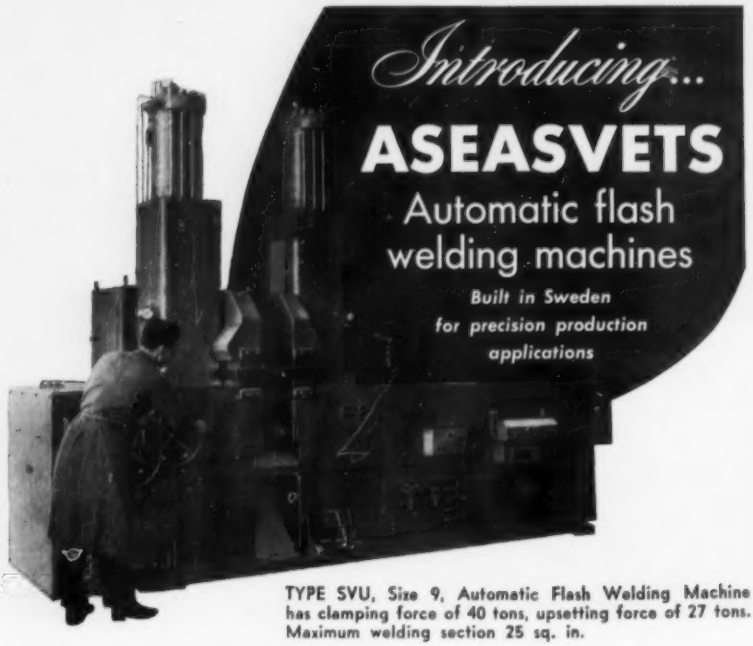
Welding High-Strength Low-Alloy Steel

To illustrate the use of such equipment, the lecturer cited an investigation of the weldability of "T-1" steel†, a low-carbon low-alloy steel for pressure vessels and other uses where the metal should carry perhaps double the unit stress of the conventional boiler and structural steels. Since this new steel comes from the mill in quenched and tempered condition, it is necessary that the good properties (strength and toughness) be unimpaired at welded joints.

Ordinarily, when hardenable steels of medium carbon content are welded, brittle martensite is formed in the heat-affected zone and reduces the notch toughness. This can be avoided by reducing the cooling rate, either by preheating the weldment or increasing the energy input of the arc. Either of these palliatives causes the austenite to transform into

*0.20 C, 0.80 Mn, 0.5 Ni, 0.5 Cr, 0.20 Mo.

†"Carilloy T-1" is produced by U.S. Steel Corp. A typical analysis is 0.15 C, 1.00 Mn, 0.90 Ni, 0.50 Cr, 0.50 Mo, 0.35 Cu, 0.05 V, boron and aluminum treated. See *Metal Progress*, September 1954, p. 82.



TYPE SVU, Size 9, Automatic Flash Welding Machine has clamping force of 40 tons, upsetting force of 27 tons. Maximum welding section 25 sq. in.

Known abroad for their precision performance, ASEASVETS Type SVU Automatic Flash Welding Machines are now available in the United States.

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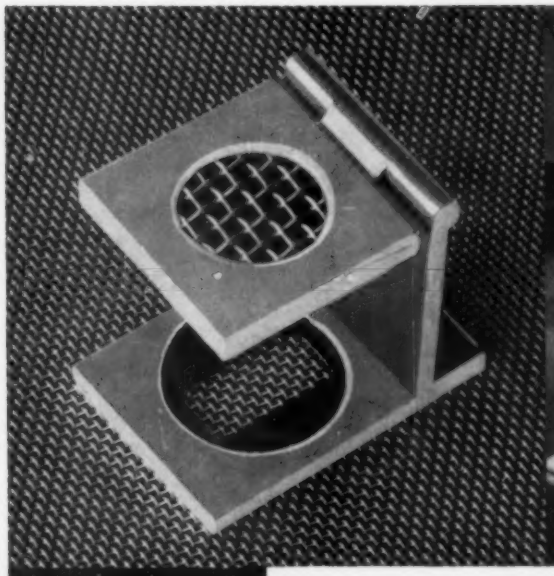

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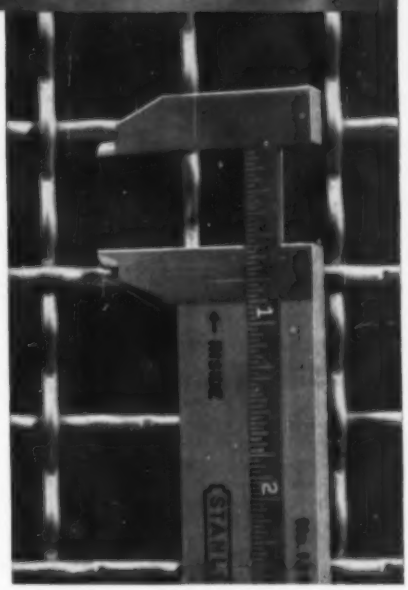

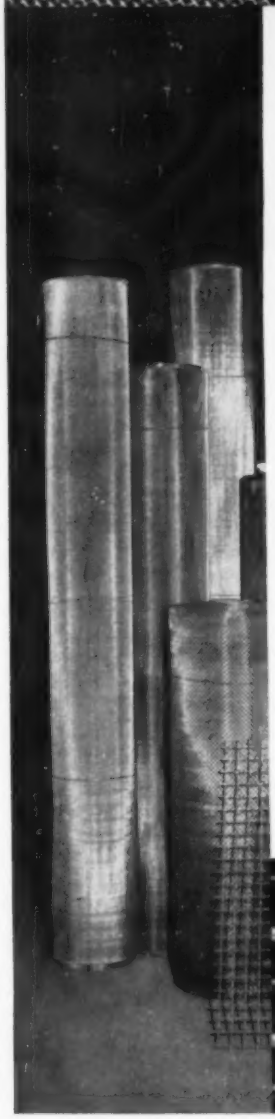

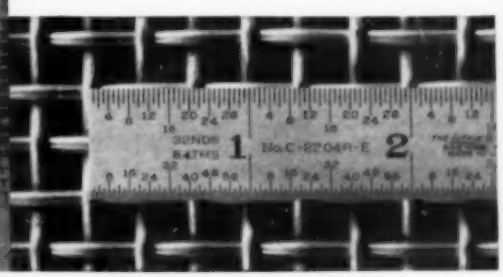

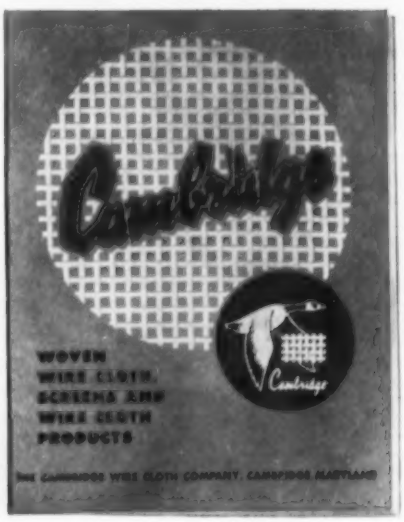

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Building such muffles is a job that requires experienced engineering design as well as exceptional skills and craftsmanship in handling special alloy fabrication. Rolock offers you both these essentials. A constantly growing file of successful case histories shows important long-range savings to the muffle user. Let us quote on your next job . . . whether it's a standard replacement or one presenting problems to be solved.

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ZRL3X8

Weldability . . .

bainite at a higher temperature rather than wait and transform into martensite at a lower temperature.

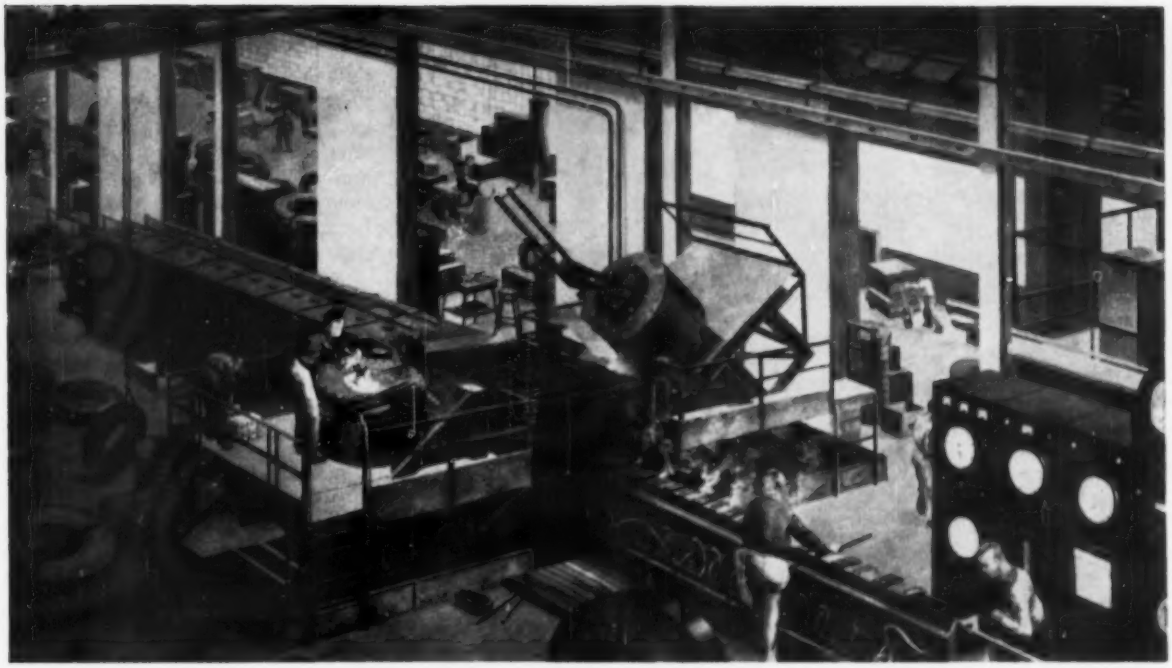
On the other hand, martensite formed in low-carbon steel has good strength, reasonable ductility and may even have high notch toughness (Charpy values).

To discover what the situation would be, several test pieces similar to those shown in Fig. 1 were prepared by subjecting them to the actual temperature cycles experienced at various distances from the fusion zone in a weld in ½-in. steel plate. These are indicated in Fig. 2. Several series of such specimens were tested at various temperatures to determine the temperature of transition from fibrous to 50% shear fracture, and for ductility transition (below to above 10 ft-lb. energy absorption).

The general trend indicates a steady rise in fracture-transition temperatures (embrittlement) as one approaches the fusion zone except in the samples tested to a maximum of 1800° F. (0.326 in. from fusion) where recrystallization to a fine-grained microstructure complicates matters. In general, ductility transition temperatures are lowered as the locations recede from the weld fusion line, but at greater distances this gradually increases to the transition temperature of the unaffected plate.

With the energy input used, microstructures of low-carbon martensite formed after cooling from all peak temperatures above A_3, and this microstructure has good impact properties. Decreasing the weld cooling rates by a preheat would be expected to affect notch toughness unfavorably, since it would likely result in a mixed structure of ferrite and high-carbon martensite. Since preheating during fabrication is common, either to minimize the effect of hydrogen (a potential source of underbead cracking), and since the high energy input of submerged-arc techniques will heat a larger volume of metal and retard its cooling later, other thermal cycles characteristic of these shop conditions were reproduced and samples were tested.

Figure 3 summarizes these results found by the synthetic specimen



60 CYCLE INDUCTION MELTING OF HIGH LEADED BRONZES

15 years ago, THE CLEVELAND GRAPHITE BRONZE COMPANY, division of CLEVITE CORPORATION, pioneered 60 CYCLE INDUCTION MELTING of bronzes with up to 35% lead. Special furnaces developed by AJAX for this difficult job are an important element in their unique continuous production line for steel-backed bronze bearing strip. 60 CYCLE INDUCTION MELTING furnaces resulted in substantial improvements and cost savings over gas-fired units used earlier for that purpose. Today, CLEVITE operates six continuous lines in this country and abroad with AJAX 60 CYCLE INDUCTION MELTING furnaces, producing enough strip to make 130 million bearings and bushings per year.

The heavy duty 60 cycle inductor developed by AJAX and pioneered by CLEVITE will attain a lining life of one year with bronzes of substantial lead content. Electromagnetic stirring assures uniform alloy and close temperature control. Compared to externally fired equipment, metal loss savings run into many thousands of dollars per year. Recently, several large producers of leaded bronze castings converted their foundries entirely to 60 CYCLE INDUCTION MELTING.

While this is one of the most difficult metals to handle, the advantages of 60 CYCLE INDUCTION MELTING stand out today wherever copper alloys are melted. As specialists in 60 CYCLE INDUCTION MELTING, we have developed furnace types to best fill each application.

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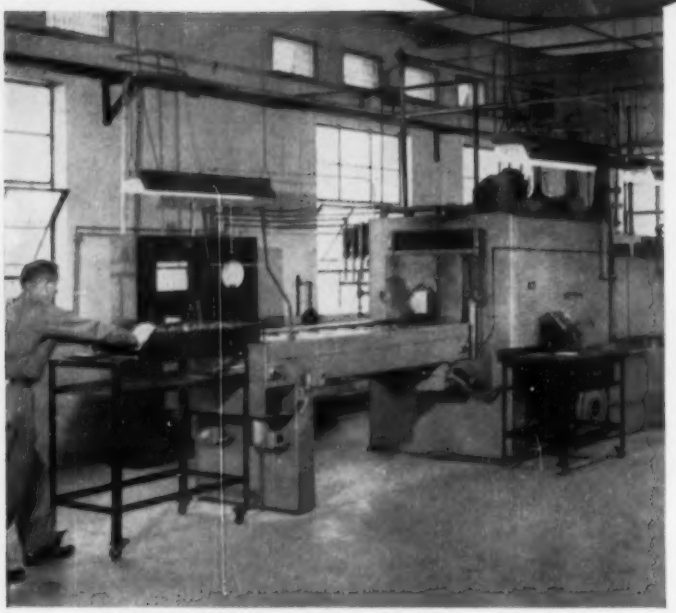


Hevi-Duty furnace earns $1,000 per month for Bedford Gear

The installation of a Hevi-Duty Clean-Line, automatic, heat treat unit has *eliminated $1,000 per month in scrap losses* for Bedford Gear and Machine Products Company, Bedford, Ohio.

In addition to the elimination of rejects, savings in time, handling and outside heat treating costs have been realized.

The Clean-Line installation includes a Carbonitrider, Washer, Atmosphere Draw Furnace and a 1000 CFH Endothermic Generator. All loading tables are the same height, enabling Bedford to transfer loaded baskets from one unit to another on a dolly, with no lifting or straining. Once loaded, the individual parts are not handled again until they come out of the draw, completely heat treated.

Carburizing is usually done at 1700° F. with case depths of .030 in. obtained in three hours at heat. Carbonitriding is run at 1550° F. to 1625° F., depending upon case depths desired, core hardness and bore size to be held. Automatic control of the quench oil temperature between 150° F. and 250° F. also helps control size which, in many instances, is held to within .001 in.

Bedford's savings over previous operations and elimination of rejects will pay for the new equipment in a matter of months. Modern equipment can improve your costs and quality. Let us send you a detailed bulletin on Hevi-Duty Clean-Line equipment — and arrange for an engineer to call and show you ways to reduce costs, improve quality. Write for Bulletin D-100.

- Industrial Furnaces electric and fuel
- Laboratory Furnaces
- Dry Type Transformers
- Constant Current Regulators

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Weldability . . .

techniques briefly described for regions reaching a temperature of 2400° F. next to the fusion zone in ½-in. plates of "T-1" welded with arcs having 47,000 joules per in. energy input. A 500° F. preheat, for example, raises the ductility transition temperature from —138 to +25° F., and the fracture transition temperature from 10 to 150° F.

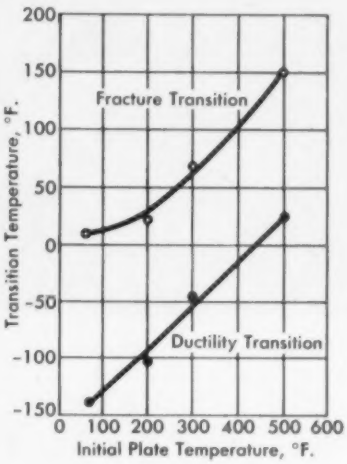


Fig. 3 — Relation of Ductility Transition Temperature (for 10 Ft-Lb. Charpy) and Fracture Transition (50% Shear Type) in Welds in ½-In. "T-1" Steel Plate

Table I represents an extension of these experiments to predict safe welding procedures (maximum energy input) for a variety of preheat temperatures and thicknesses of "T-1" plate so the joint will posses at least 10 ft-lb. Charpy V-notch toughness at —50° F.

In summary, preheating of "T-1" may be necessary under welding conditions involving high restraint, moisture on the steel, too high moisture content in the electrodes, or

Table I — Safe Heat Inputs (Joules Per In.) for Welds in "T-1"

Plate Thickness	Preheat Temperature		
	None	300° F.	500° F.
¼ in.	36,000	24,000	15,000
½	70,000	47,000	34,000
¾	121,000	82,000	51,000
1	Any	126,000	70,000
1¼	Any	175,000	88,000
1½	Any	Any	106,000

low ductility of weld metal. When preheating or high-energy inputs are required, these welding variables must be controlled and limited to preserve notch toughness of the heat-affected zone. These limitations are only restrictive in relatively thin plates. In thicker plates these limits pose little or no problem.

E.E.T.

Aircraft Quality Steels

Digest of "Aircraft Quality Steels — Medium and Low-Alloy Type", by L. F. Barnhardt and P. Adams, Atlas Steels Ltd., Welland, Ont. Paper presented at the A.I.M.E. Electric Furnace Steel Conference, Pittsburgh, December 1957.

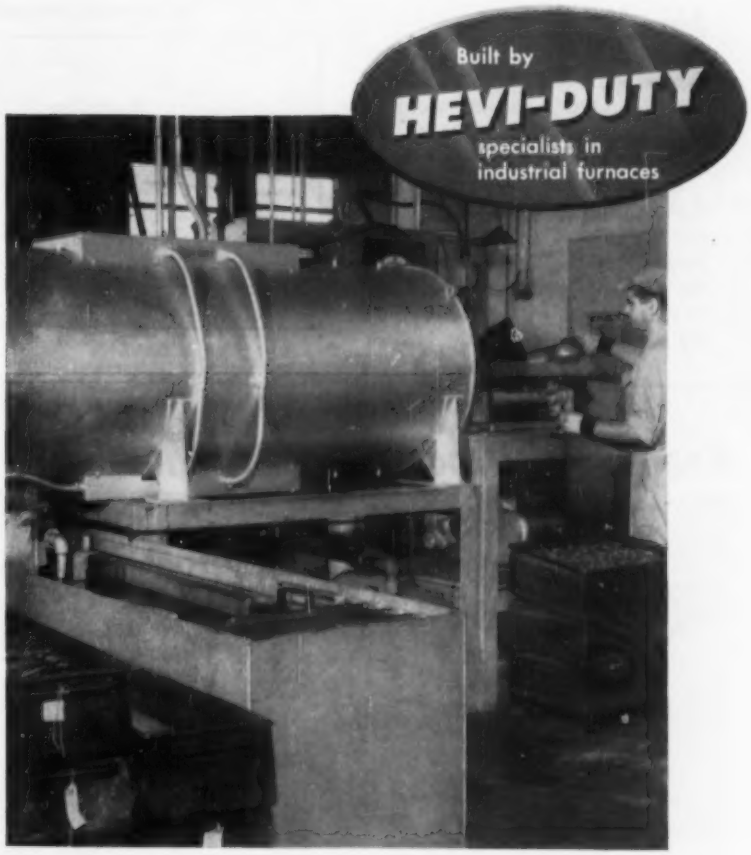
THE INCREASING USE of ultra high-strength steels in aircraft production has required ever more extreme care in the manufacture and testing of aircraft quality steel. One example is the production of a modified 4340 steel to meet a 260,000 to 280,000 lb. tensile strength level. For this material, tempering in the 400° F. range is necessary to avoid the temper brittleness zone (500 to 700° F.). These tempering temperatures, unfortunately, are not always successful in relieving the internal stresses, even when long tempering cycles are used.

Retained austenite, hydrogen content, and nonmetallic inclusions must also be controlled.

The factors necessary for toughness at high-strength levels have been established as follows: (*a*) a tempered martensitic structure; (*b*) low carbon content, consistent with desired strength; (*c*) avoidance of brittle-range tempering temperatures.

To attain the desired conditions, the ultimate in melting practice is required. Every step is important. To begin with, bottom and lining of the furnace must be in good condition, scrap used in the charge should be low in phosphorus and sulphur and not contaminated with tin or copper, and limestone and ore should be dry. The melt-down composition of the carbon must be at least 0.15% above the specified range to insure a good ore boil.

The bath during melting is 3020 to 3050° F., as measured by optical pyrometer. If colder, the temperature is raised quickly before starting



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But improved quality is only half the story. Parts are fed onto the hearth and progress through heat and quench cycles automatically. This eliminates jig and wire time and enables them to step up production from 20 lb an hour to 60 lb an hour. At the same time, operating costs per unit of production have been cut in half.

Parts processed in this furnace are springs, washers and screw machine parts. They are treated under protective atmosphere at temperatures varying from 1450° F. to 1850° F. and quenched in oil. All parts come out at maximum hardness for each metal.

For more information on the performance of Hevi-Duty Shaker Hearth Furnaces, write for Bulletin 1057.

- Industrial Furnaces electric and fuel
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HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Aircraft Steels . . .

the ore boil. A high bath temperature during this period insures a very fluid melt; this promotes the rising of inclusions into the slag.

Iron ore is added for a steady, vigorous boil over a 15 to 20-min. period. For low-carbon specifications, a short oxygen blow completes the boiling period. The hydrogen level is then at its lowest and only dry materials must enter the furnace after this period. The bath is now in a highly oxidized condition; removal of this oxygen is necessary. This is done by adding carbon to provide a vigorous boil that lowers the oxygen content through evolution of carbon monoxide. The second step in deoxidation is the manganese reboil. A vigorous reaction is obtained by adding up to 0.40% manganese as high-carbon ferromanganese. Following slag off, additions are made to the bare bath in the following sequence: (*a*) carbon as ground electrode, (*b*) ferromanganese, (*c*) calcium silicide, (*d*) aluminum, (*e*) ferrochromium — up to 1.00% of bath weight.

Alloys other than carbon should, in general, be aimed high. Molybdenum, chromium, manganese, silicon, and vanadium each raise the tensile strength of fully quenched and tempered steels. Burnt lime, silica sand, fluorspar, and fine coke now produce a carbide slag which should be fluid and active with low FeO content. Preliminary tests are taken during the working period. When these are reported, adjustments of carbon and manganese are made, and 50% lump ferrosilicon is added 30 min. before tap. Following absorption of the silicon addition, the bath is thoroughly stirred and temperature determined by immersion thermocouple. Tapping temperature is very critical in the production of clean steel; to avoid ladle skulls, it should be approximately 20° hotter than that of similar steels for less critical applications. When tapped (into a ladle which must be clean), additions of calcium silicide and aluminum are made. Furnace spouts should be in good condition to give a compact metal stream; a splashing stream can be excessively oxidized and result in an increase in inclusions. Good ladle and nozzle refractories

Mechanical Properties of Aircraft Quality Steels

	Longitudinal		Transverse	
	Required	Av. Results	Required	Av. Results
Tensile strength	260,000 to 280,000	264,000	260,000 to 280,000	263,000
Yield strength	217,000 min.	217,000+	217,000 min.	217,000+
Elongation	9.0% min.	12.0%	4.52 min.	6.5%
Reduction in area	35.0% min.	43.0%	8.0% min.	19.5%
V-notch Izod	11 ft-lb. min.	16 ft-lb.	—	—

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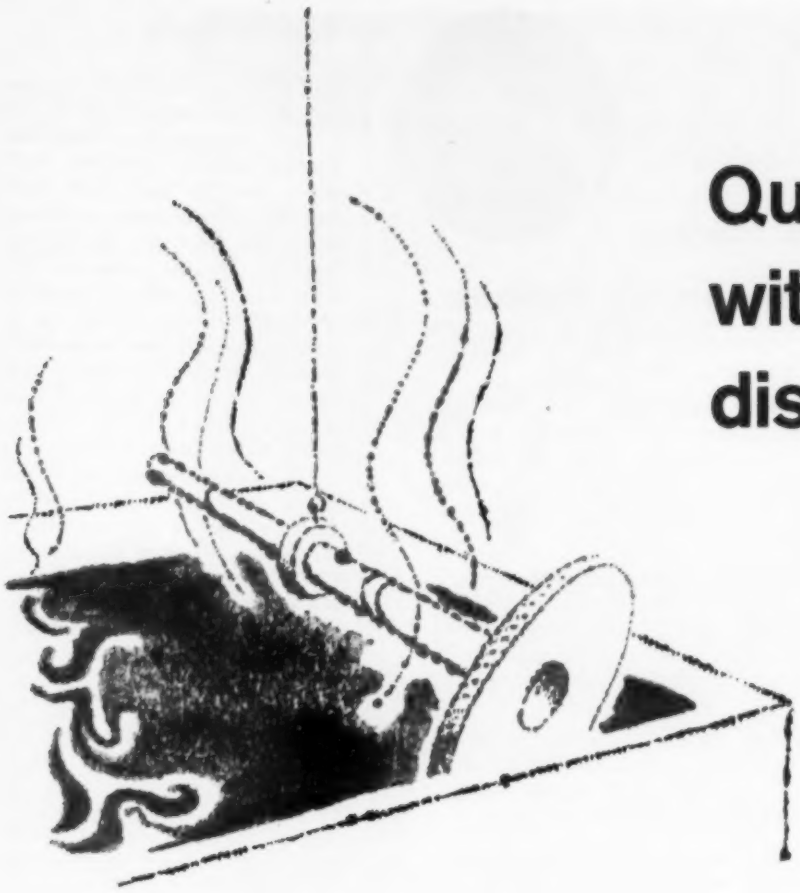
SALES ENGINEERS: Atlanta, Baltimore, Boston, Buffalo, Charlotte, N. C., Chicago, Cleveland, Dallas, Detroit, Fall River, Mass., Greenville, S. C., Louisville, New York, Philadelphia, Pittsburgh, Rochester, St. Louis, St. Paul, Tampa, Canadian Rep., Peckover's Ltd., Toronto, Montreal.



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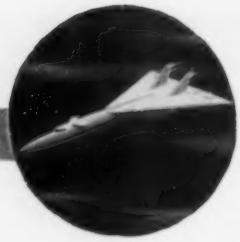


PROGRESS REPORT

Internally-cooled blades and vanes for gas-turbine engines

THE NEED—Present uncooled gas turbines have bumped against the top thermal limits of the metals currently used for turbine components. Only by finding ways to increase the turbine inlet temperatures without affecting temperatures of such parts as turbine blades and vanes can gas-turbine engines of greater thrust and efficiency be made.

THE OBJECTIVE—An investigation was made in the TAPCO Group of Thompson Ramo Wooldridge Inc., to develop a way to produce internally-cooled blades and vanes. By cooling these parts, turbine inlet temperatures can be increased as much as 200°F over present limiting temperatures. This increase should permit much higher thrusts to be developed.

Cooling of turbine components can be achieved either by air or water. Air-cooling seems to be more convenient to apply. For this reason, TAPCO investigations have been directed to the production of blades and vanes with internal air passages.

THE METHODS—Fabrication methods reviewed includes powder metallurgy, casting, rolling, forging, and extrusion. TAPCO established projects on rolling, forging, and extrusion methods.

THE RESULTS—Practical methods have been developed at the TAPCO Group for drilling holes economically in such alloys as Udimet 500, Waspalloy and other blade materials.

Extrusion of pierced preforms has been accomplished by the TAPCO Group.

TAPCO engineers and metallurgists have developed practical methods of rolling pierced preforms to produce blades of accurate finished size and contour while maintaining the integrity of internal air passages during forming operations.

Both tapered and straight air passages have been achieved by methods and equipment suitable for mass production of air-cooled blades.

Limitations on the commercially feasible rolling of air-cooled blades and vanes have been established after considerable research on several rolling methods.

TO SUM UP—The TAPCO Group of Thompson Ramo Wooldridge Inc. is able to produce air-cooled blades and vanes from materials currently available to meet the requirements of gas-turbine manufacturers for higher turbine inlet temperatures. When may a TAPCO engineer call to give you complete information and design data?

TRW

TAPCO GROUP

Thompson Ramo Wooldridge Inc.

Dept. MP-459 • Cleveland 17, Ohio

Aircraft Steels . . .

should be used exclusively since fireclay, through corrosive attack, also provides alumina-silicate inclusions. Pouring stream from the ladle nozzle must be solid (with clean shut-offs and a minimum of icicling) into molds carefully prepared and free from foreign material. The meticulous care which attends all phases of the melting process is intended to provide the cleanest steel possible. It should be understood, however, that entirely clean steel has never been made and probably cannot be made commercially.

The routine testing program for aircraft quality steels has had to be tightened considerably in order to meet the demands of the industry. Top, middle, and bottom tests from first, middle and last ingots are the usual locations step-tested by magnetic methods for cleanliness. Tests are cut from rolled billets at the required positions and forged to a diameter of 2½ in. Two steps are then machined (see Fig. 1) for magnetic particle inspection; rating is done according to A.S.T.M. specification E 45-51. Mechanical properties are also specified; requirements and results obtained from 96 tests are shown in the table on p. 136.

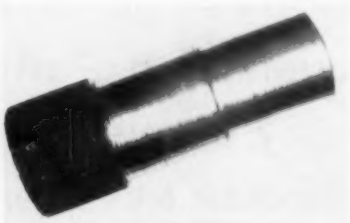
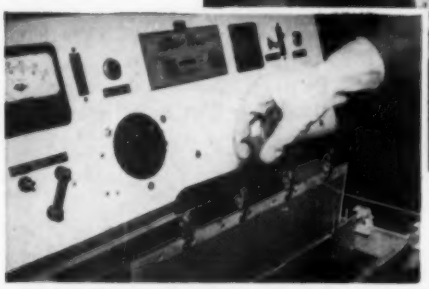


Fig. 1—Standard Step Test. The steps are 2½ × 2½ in. diameter and 2½ × 2¼ in. diameter

Continuous effort must be maintained to improve the cleanliness and properties of aircraft quality steels. However, there are limitations to the cleanliness obtainable with electric furnace steel. Products of deoxidation cannot be avoided; air and refractories are also a source of nonmetallic inclusions. Vacuum melting processes, despite their high cost, may be the only answer.

It should be mentioned that the melting practices employed at Atlas

Two of the four Sel-Rex Jet Platers —complete electroplating facilities in 34" x 28" x 33" cabinets. This equipment is used as a step in the process of producing some of the printed wiring boards for the SAGE computer, and for experimental equipment currently under development.



IBM Plating operator removes printed wiring board from Sel-Rex Jet Plater where it has been plated with Sel-Rex Bright Gold. The Jet Platers assure optimum conditions for the electrodeposition of Sel-Rex Bright Gold for this exacting application.

Heart of the SAGE System is the 275 ton IBM computer, one of the world's largest and most reliable. Shown here are some of the computer frames containing pluggable electronic units that perform the data processing involved in solving air defense problems.

SEL-REX BRIGHT GOLD AND 4 JET PLATERS HELP PROVIDE "BUILT-IN" RELIABILITY TO IBM SAGE COMPUTER

When it comes to protecting our country from possible surprise air-attack, only the best, most reliable instruments and equipment will do. Understandably, IBM was chosen to build the 275 ton computer pictured in part at the lower left, which is the heart of our SAGE System. The SAGE computer performs millions of computations at lightning speed, and continuously checks them—*automatically.*

Approximately 7,300 pluggable units containing printed card assemblies are used in this computer. Needless to state, the proper functioning of these units is essential. Sel-Rex Bright Gold, in four Jet Platers, is used in the manufacture of the IBM SAGE computer, and other military equipment under development. Built-in reliability—for which IBM equipment is famous the world over—assures us all of constant electronic watchfulness 24 hours a day.

Sel-Rex can offer built-in reliability to your product through the unique metallurgical properties of a precious metal—or by designing plating or metal finishing equipment to your specific requirements...from a single piece of equipment to a complete facility. Our latest catalog—#CHP—gives details.

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Aircraft Steels . . .

Steels Ltd., which are discussed in this article, are not necessarily used by other producers. Melting practices vary, sometimes widely, from mill to mill. However, the basic requirement in Atlas practice – meticulous care in every phase of melting and pouring – is adhered to by all producers.

C.R.W.

Use of Vibration in Casting

Digest of "Vibration Can Improve Casting Quality", by A. H. Freedman, J. F. Wallace and F. A. Carbonaro, *Foundry*, Vol. 85, November 1957, p. 98-101.

FOUNDRIES producing high-quality castings to exacting specifications and optimum properties have become interested in a new metallurgical development – the use of vibration. Vibrations applied to molten and solidifying metals are beneficial because they promote degassing, grain refinement and an improvement in the detail of castings because of an increase in apparent fluidity.

Both European and American investigators have demonstrated that aluminum, copper and steel alloys can be effectively degassed on a commercial scale by other means, and it does not appear feasible to utilize vibrations for this purpose in operating foundries. However, the as-cast grain size can be appreciably refined and the mechanical properties improved by either sonic or ultrasonic vibration. A series of photomicrographs (Fig. 1) clearly demonstrate the influence of 60-cycle and 20-kc. vibrations on an aluminum-copper alloy. The effect is especially pronounced on columnar structures.

By using vibrations during casting of leaded yellow brass, grains are

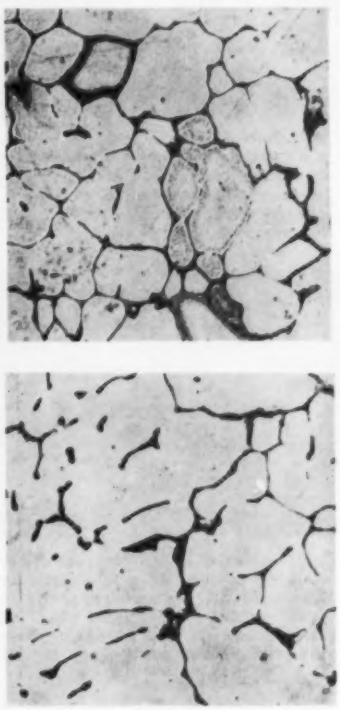

Fig. 1 – Influence of 20-Kc. Vibrations on Aluminum Alloy With 4% Copper, Not Grain Refined. Top, vibrated; bottom, not vibrated. Grain diameter decreased by one half. Tensile strength increased from 19,400 to 26,400 psi. Elongation almost doubled. 45 ×

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Vibration Casting . . .

reduced to only 5% of their original statically cast size. This refinement is accompanied by an improvement in tensile strength of almost 25%. Ductility is not influenced by this increase in strength. Figure 2 shows the influence of vibration on this material.

Applied vibrations may also reduce the amount of segregation even though the grain size may remain substantially unaltered. This is shown in Fig. 3 in a tungsten-molybdenum toolsteel cast in a hot investment mold.

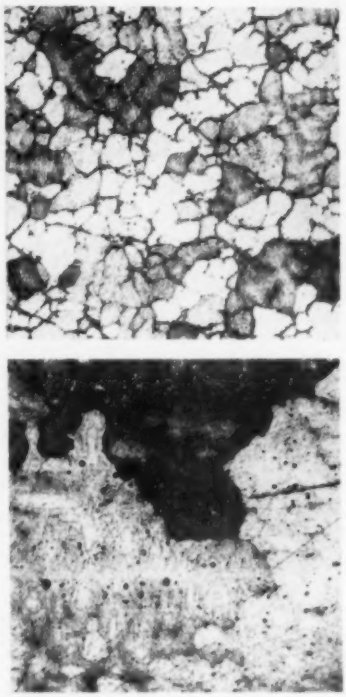

Fig. 2 – Influence of 60-Cycle Vibration on Leaded Yellow Brass. Top, vibrated; bottom, not vibrated. Grain diameter decreased by one half. Tensile strength increased from 31,100 to 38,800 psi. 50 ×

Use of vibrations does not always result in significant improvements in properties or structure; rather, constituents may be coarsened. The mechanism of solidification of the metal provides the reason for this apparently paradoxical behavior. The most beneficial results obtain when the metal solidifies as a simple solid solution or pure metal. More complex solid solutions such as high-

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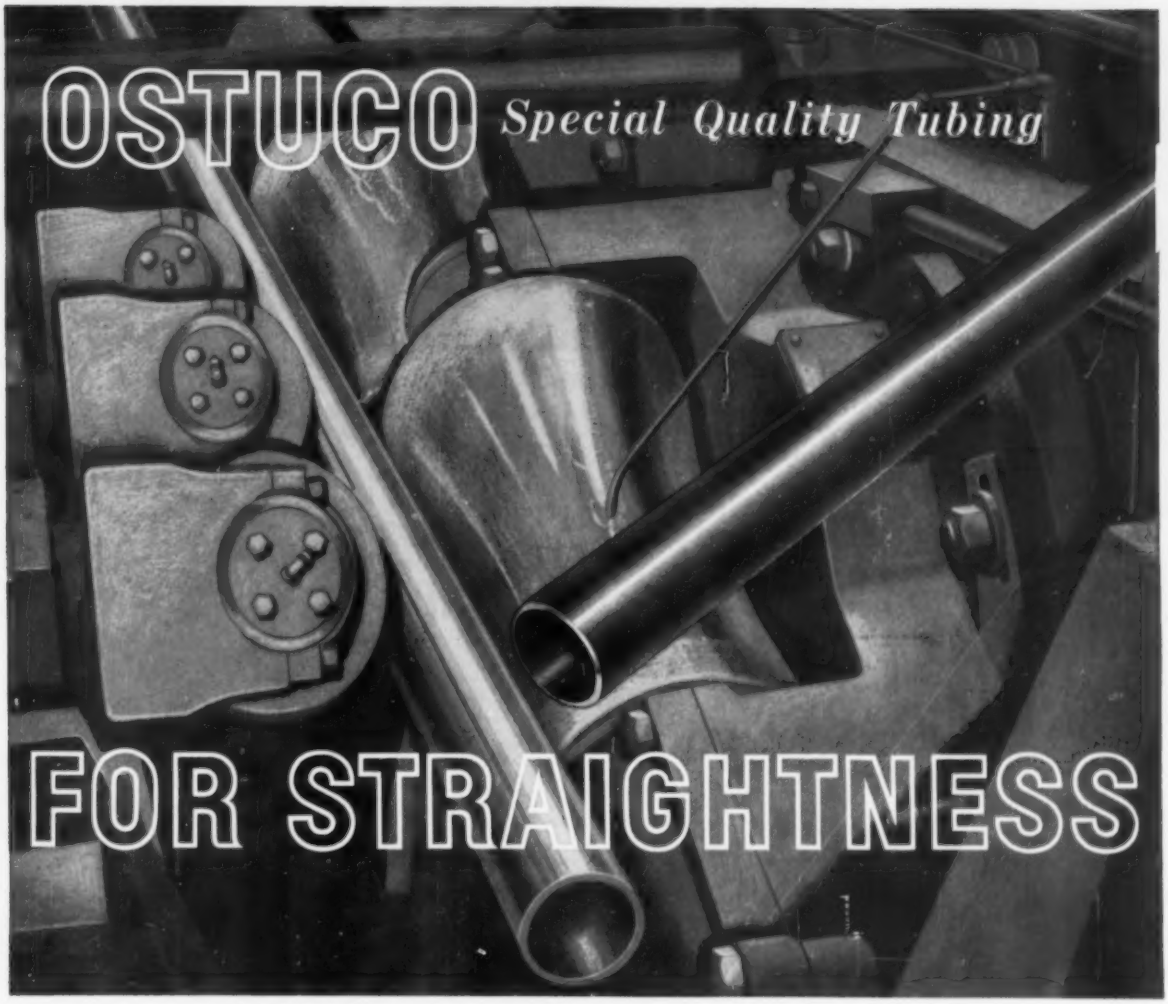

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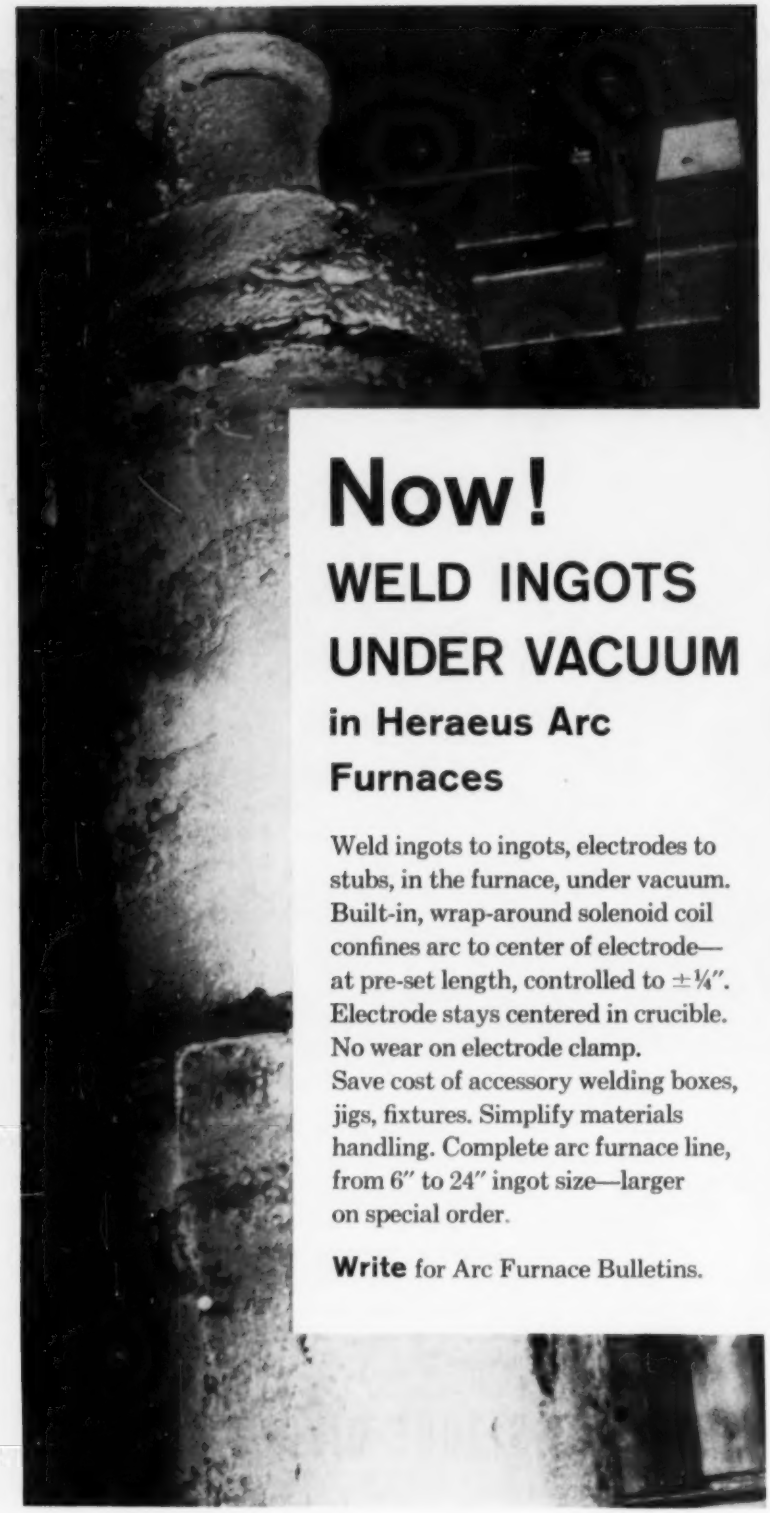

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Vibration Casting . . .

alloy toolsteel solidify with an inherently fine-grained structure because of the numerous phases present and are, therefore, little influenced by subsequent grain-refining action. Metals solidifying as eutectics are coarsened by vibration, and mechanical properties reduced.

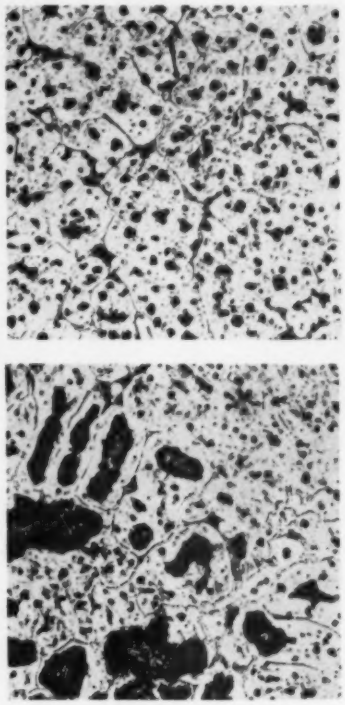
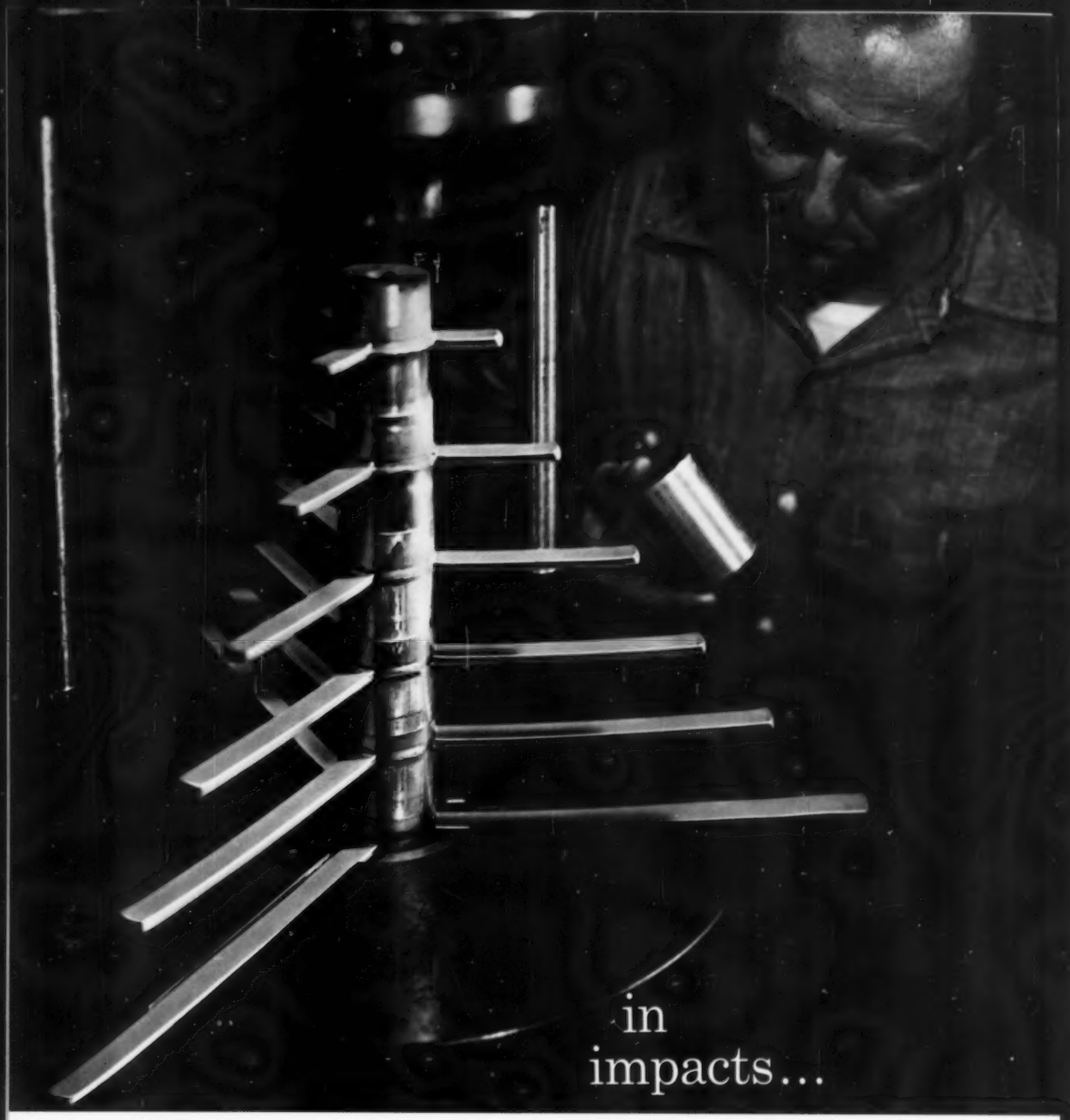


Fig. 3 — Influence of 60-Cycle Vibration on the As-Cast Microstructure of a Tungsten-Molybdenum Toolsteel. Top, vibrated; bottom, not vibrated. 200 ×

The mold must be sufficiently rigid to withstand the vibrational energy. High amplitudes associated with low-frequency vibrations will shatter a conventional green sand mold. Low amplitudes of ultrasonic frequencies can be safely utilized with the weaker materials such as green sand and plaster.

Fluidity, as measured by foundrymen, is a function of superheat and composition. However, surface tension exerts some influence on the minimum cast section thickness possible. This surface tension can be reduced by vibration.

The authors have determined that the increase in apparent fluidity resulting from vibrations is beneficial



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Vibration Casting . . .

for commercial investment castings, where a significant improvement in mold filling capacity and casting detail was observed. However, the use of vibrations will not compensate for poor foundry practice, nor will they, by themselves, be sufficient to insure all desired improvements. Further work in this field is suggested. H. J. HEINE

Improvement of Castings by Press Forging

Digest of "Development of a Method to Improve Castings by Press Forging", by Andrew H. Murphy and Lyle L. Clark, Armour Research Foundation, under Air Force Contract No. AF 33 (600)—30159, administered by Air Materiel Command, Wright-Patterson Air Force Base, Ohio. 203 p.

AT THE REQUEST of U.S. Air Force Air Materiel Command, Armour Research Foundation of Illinois Institute of Technology studied press forging in a closed die to determine if limited deformation of a casting would improve certain mechanical properties of the cast part.

Three aircraft structural materials were chosen: aluminum, magnesium and titanium casting alloys. The objectives of the program were:

1. To establish the best forging conditions (to obtain optimum properties).

2. To investigate the feasibility of casting dies to shape for press forging parts.

3. To verify that increase in strength is obtained by pressing a casting. A production aircraft casting was to be selected, press forged and tested to destruction.

Several hundred test bars, having uniform mechanical properties were cast so that a series of different deformations, forging temperatures and heat treatments could be investigated.

After completing the design of the aluminum test casting, specimens were cast under very close control of all production variables. Only castings that appeared sound and reproducible after X-ray inspection were used. Magnesium-base alloy test bar design was the same as that

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(Instruments are made by Leeds & Northrup Co., and those shown here are in use at L&N's North Wales, Pa., plant.)

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Castings . . .

used for aluminum alloys, principally because many of the gating and risering problems were similar. It would also have been desirable to have the titanium specimens cut from a casting; however, foundry practice is not well enough developed to consider such an approach so that test bars with a cast structure had to be cut from a cast titanium ingot.

The press forging work was done on a 1000-ton hydraulic press, using three different forging temperatures on material in different heat treated conditions. A range of forging deformations was used at each temperature and for each heat treated condition.

The dies were machined from Type 4340 steel and heat treated to a hardness of Rockwell C-40. Electric heating elements were placed along slots on the side of the die. The bottom of each die block had an opening to accommodate thermocouple lead wires. All aluminum bars (alloy 356) used for the press forging investigation were solution heat treated at 1010° F. for 13 hr. and water quenched. Bars to be press forged in the aged condition were aged at 315° F. for 3½ hr. Bars press forged in the solution treated condition were given this same aging treatment after forging.

Aluminum bars forged at room temperature in the solution heat treated condition could be deformed up to 40% without any ill effect; however, bars forged in the aged condition at room temperature were prone to edge crack at deformations of 20% and above. Raising the forging temperature to 300° F. eliminated this undesirable condition. An evaluation of the tests shows that there is a definite increase in yield and ultimate strength as the forging deformation increases. Thus there is an advantage in forming the material in the aged condition. Optimum press forging conditions can be chosen for any particular casting once the maximum forging deformation and minimum elongation are established.

Results of press forging cast magnesium alloy AZ 92 test bars indicated that increases in mechanical properties of the order of 20% are possible, without loss of elongation.

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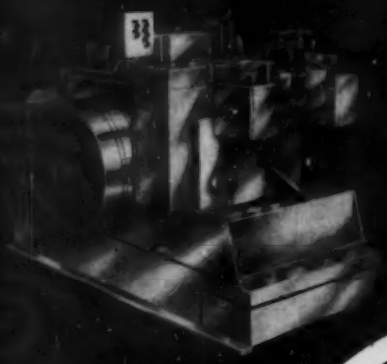

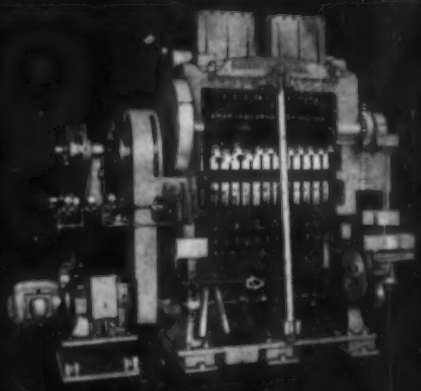

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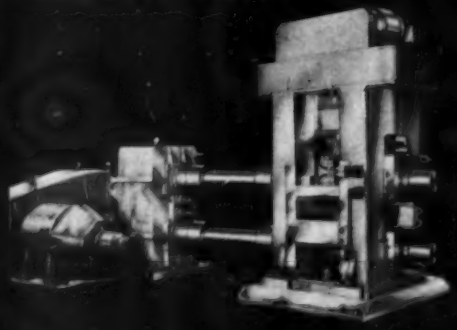

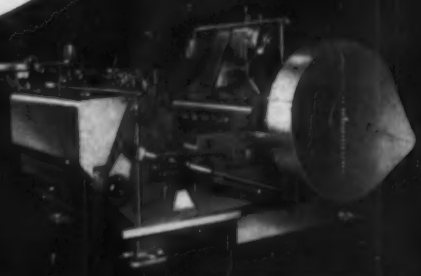

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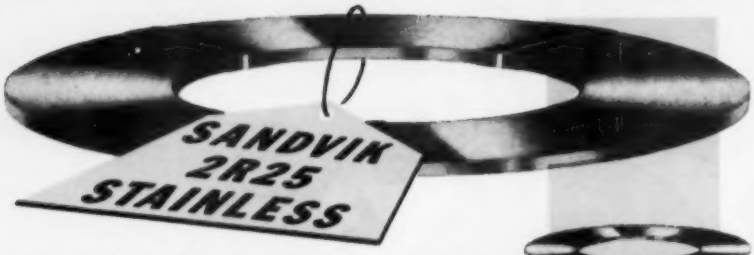

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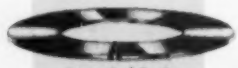
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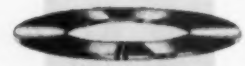
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Castings . . .

The properties of a press-forged magnesium casting were found to be equal to those of aluminum castings in many instances. No heat treatment is known which will improve a magnesium casting to that extent.

Because commercial titanium castings have not been developed to any large extent, work was confined to a feasibility study to determine what forging problems to expect. An alloy containing 6% Al, 4% V was selected for the tests. The material was forged in the solution heat treated condition.

Up to a forging temperature of 1200° F., all pieces cracked. At 1200° F. the material could be deformed about 15% before failure, while at 1400° F. the samples withstood up to 40% deformation without showing defects. The dies were held at the same temperature as the samples, since dies at a lower temperature chill the sample just prior to and during forging, and the true forging temperature becomes undefined. When the bars were deformed only 5%, the ultimate strength increased from 133,000 to 139,700 psi.

Very little work has been done on producing casting dies to shape, and there is a scarcity of information in the literature. In casting dies, the most important factors are surface finish and dimensional control.

Die materials selected for investigation included copper-base and beryllium-copper alloys, and cast iron. A cast beryllium-copper die set was produced with good surface finish and dimensional accuracy. This cast die was used to press more than 100 castings at 400° F., and no marked die wear was noted. As a result, it was concluded that the production of cast dies for press forging is a feasible and inexpensive process.

To demonstrate the increase in strength that could be obtained by press forging a casting, a production aircraft component was selected, pressed and tested to destruction in a special fixture which subjected the part to simulated service conditions under actual loads. The part was a cast magnesium alloy (AZ 92) elevator control arm used in the T-34 aircraft. Ultimate strength increased 17.7% (from 1970 to 2310

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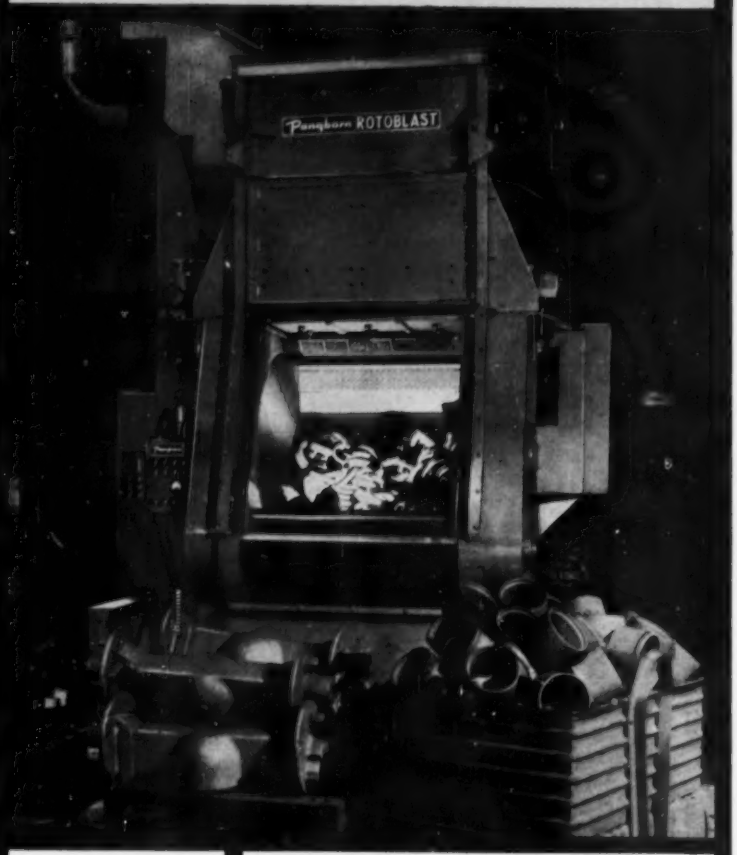

Pangborn Rotoblast cuts man-hours per day from 24 to 15 at Meadville Malleable Iron

The investment in a new 20 cu. ft. Pangborn Rotoblast Barrel has really paid off for Meadville Malleable Iron Co., Meadville, Pa.! By switching from a competitive barrel of about 12 cu. ft. capacity, the firm now cleans loads three times as large in half the time. Today tote box loads averaging 1900 lbs. each are cleaned in 4—5 minute cleaning cycles. As a result, the Rotoblast Barrel has cut 24 man-hours per day to 15 man-hours in the cleaning department and greatly improved the quality of the work.

How much time and money can Pangborn Rotoblast save you? It would pay you to talk to the Pangborn man in your area. Or write PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

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Castings . . .

psi.), and in yield strength, 39.5% (from 1140 to 1590 psi.).

The tests showed that press forging of a casting is a feasible production process and that the increases in strength can be predicted closely by pressing cast test bars of the same alloy. Not all alloys, however, benefit from this process, and some materials show much more improvement than others. A great deal of additional study is required to broaden the base of our knowledge in this field. HANS HEINE

Metal Powders . . .

(*Continued from p.* 116)

may be desirable to extrude unpressed powder in a can. However, before extrusion can commence, a considerable amount of densification must occur in the container. Also, the can sometimes wrinkles; while this may be reduced by using a thinner can, there is a lower limit to the thickness of the sheath. The walls of the can will become thinner during extrusion, and continuity must be maintained.

The penetrator ram mentioned above reduces wrinkling. When it breaks through the end plate, it compresses the powder in the can, and folding is minimized. Once consolidation is achieved, the billet is either extruded without the can, or in the sheathed condition.

In certain instances, such as when relatively complex sections with good surface finish are required, the operation is divided into two steps. First, the extrusion press, with a closure plate and a penetrator ram, "upsets" a billet (Fig. 3). Then the unextruded, but consolidated, billet is ejected from the press, and the can is removed. The sheathed billet is then extruded.

Powder Extrusion Applications

Since extruded products are dense wrought shapes without precise dimensions, they must compete with normal cast and wrought materials. Consequently, they can only be of value if they cost less than conventional products, or if their properties cannot be reproduced in conventional products. In some applications, these conditions have been met.

Aluminum was one of the first materials to be extruded commercially from powder. Sintered aluminum powder (SAP) was first made by a Swiss company, Aluminium Industrie A.G. Later the Aluminum Co. of America also produced sintered aluminum powder products. The Swiss material is made from fine flake powder which is cold compacted, sintered, hot pressed and hot extruded. According to theory, pressure applied in hot working plastically deforms the powder. This breaks the oxide skin and welds the particles. The oxide skin surrounding each powder particle had, until this work was carried out, severely hampered the use of aluminum in conventional powder metallurgy since it inhibited diffusion during the sintering process.

SAP retains its properties after heating at high temperatures for prolonged periods. For example, tests show that after one month's heating at 930° F. SAP drops from a tensile strength of 58,000 to 54,000 psi. and from a yield strength of 38,000 to 37,000 psi. In contrast, conventionally produced aluminum, Al-Mn-Si, and Al-Cu-Mg all show marked losses in strength after annealing for 4 to 6 hr. at 660 to 750° F.

SAP also shows high resistance to deformation at elevated temperatures. Both tensile and stress-to-rupture properties are excellent. Its short-time tensile properties and those of a heat treated Al-Cu-Mg alloy are compared in Fig. 4. These unusual properties are attributed to the dispersion of oxide inclusions formed when the oxide skins break up. Particle size also makes a difference. When finer particles are used, oxide content is higher and distance between adjacent oxide areas is shorter. Both factors contribute to a stronger composition.

In the May 1958 issue of *Metal Progress*, R. J. Towner of the Aluminum Co. of America described aluminum alloys made from atomized powders. In them, the strengthening phases are intermetallics of the $FeAl_3$ type. Powder metallurgy produces the intermetallic constituents in a fine dispersed form that cannot be achieved by conventional processes. Properties of some of these alloys are shown in Fig. 5.

Magnesium powder is similar to aluminum in that it also is coated

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Ft. Pitt Steel Castings Div., Pittsburgh Steel Foundry Corp., McKeesport, Pa., really put Pangborn's New Rotoblast Steel Shot to the test! Ft. Pitt ran a careful six months study using S-460—involving hundreds of hours of operation—comparing Rotoblast to the best steel shot the company had found previously. Both abrasives were tested under the same conditions in a 72 cu. ft. Rotoblast Barrel.

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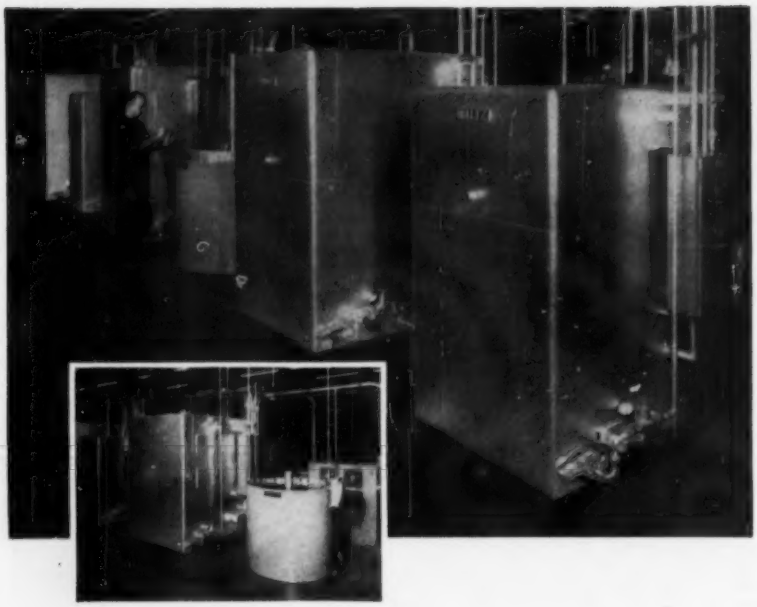

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Metal Powders . . .

with a stable, adherent oxide. However, the pyrophoricity of fine magnesium powder has usually limited experimental work to relatively coarse atomized powders. In spite of this drawback, the success with SAP led to work on magnesium powders, which also resulted in materials with good resistance to deformation at elevated temperatures. Table I on p. 116 compares properties of powder material with those of a cast billet extrusion after various heat treatments.

Beryllium fabricated by wrought powder metallurgy techniques has better ductility. Rods extruded from powder exhibit 15 to 20% uniform elongation. When vacuum cast beryllium is extruded into rods, the maximum ductility is only about 2 to 3%. When rods made by each process were examined, it was found that: (*a*) The perfection of preferred orientation is greater in rods made from powder, and (*b*) the grain size is very much finer in the powder rods. Which of these differences is primarily responsible for the markedly better ductility of beryllium parts fabricated from powder is not completely understood, but it is generally accepted that preferred orientation and grain size are the principal factors.

Some of the techniques of powder extrusion described above were first used with beryllium.*

Copper, nickel and cobalt powders have received much attention lately, in part, because of recent developments in hydrometallurgical extrusion techniques. These produce metals from their ores in the form of powders. Plants have now been built which can produce copper, nickel and cobalt powders in large quantities at costs that compare to those of virgin metal ingots. In addition, the powder product is generally purer than conventionally produced metal. The powder extrusion technique is being considered as a means of converting these powders into wrought forms without at any time melting them.

Composite materials, consisting of

*"Mechanical Working of Beryllium by Extrusion", by P. Loewenstein, A. R. Kaufmann and S. V. Arnold, The Metal Beryllium, Chapter 5D, American Society for Metals, Cleveland, 1955, p. 241.

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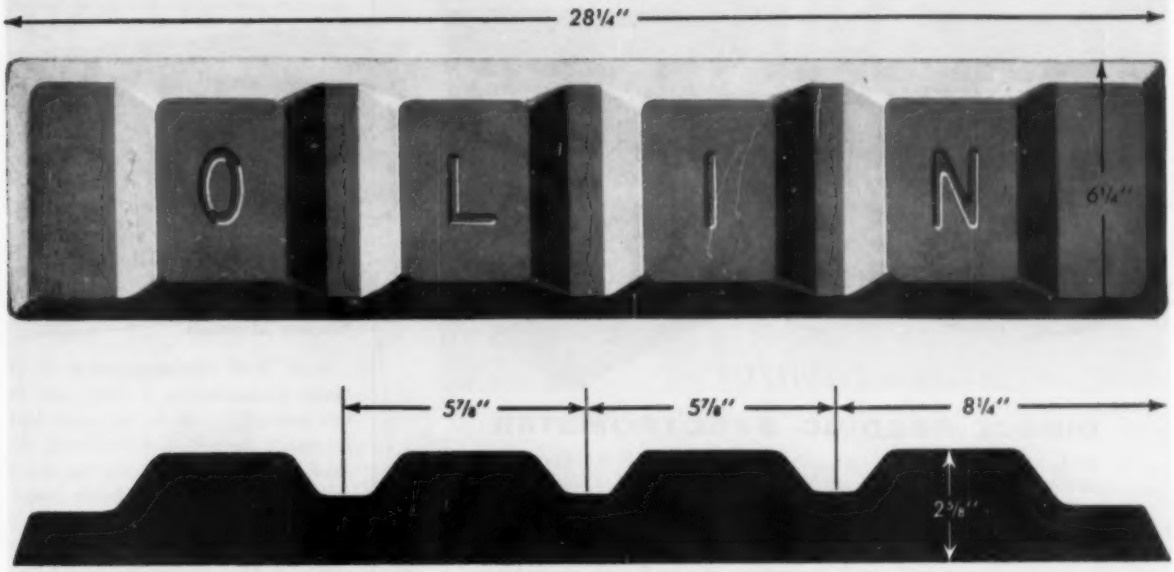

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Metal Powders . . .

insoluble metal combinations, metal and nonmetal mixtures, and alloys of unusual composition, have been produced by powder metallurgy techniques. In the past, production has been limited to small articles made in automatic presses. Now extrusion can produce such composites on a large scale.

A great variety of compositions and properties can be produced; although most products are still in the developmental stage, applications have been found for them as electrical and magnetic materials and as specialized brazing alloys. It is, however, in the nuclear and high temperature fields that their development is receiving most attention.

Nuclear Materials

Solid fuel elements must meet many requirements if they are to function satisfactorily in a nuclear reactor. They should be strong, remain constant in size during operation, and retain both fissile material and fission products. In small compact reactors operating on highly enriched fuel, elements should exhibit these properties for long periods under high neutron flux.

The dispersion-type fuel element, by distributing the particles of the fissile phase uniformly in a continuous matrix of nonfissile material, localizes radiation damage to areas immediately adjacent to the dispersed phase. This minimizes damage to the element as a whole. Also through the dispersion technique, many more combinations of fissile material and diluents can be made than is possible with alloy fuel elements. This is particularly true if the dispersion element is made by wrought powder metallurgy. Then the dispersed phase can be distributed evenly, and the particle size of the fissile material can be readily controlled.

Work on dispersion fuel elements now involves many material combinations; however, the stainless steel-uranium oxide (UO_2) combination is receiving a considerable amount of attention. Among other metals considered as matrix materials are aluminum, zirconium, columbium and molybdenum; UC and UN and a host of other fissile compounds are possible for the fuel phase.

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dispersions digest

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Acheson 'Prodag'®, spray-applied on permanent molds at Paragon Aluminum Corporation, has given them consistently higher quality castings and fewer rejects.

Better surface finish with 'Prodag' permanent mold coating is just one of the reasons why Paragon Aluminum Corporation, a Division of Detroit Harvester Company located at Monroe, Michigan, switched to this Acheson product. After four years of experimentation with other mold washes, Paragon chose 'Prodag' — Acheson semi-colloidal graphite in water — and has used it constantly the past seven years. The reasons for its choice are these; uniform consistency, excellent heat-transfer quality, and its hard, smooth, tenacious film which resists flaking and provides easier parting characteristics.

With about 95 per cent of its annual output of more than two million pounds of castings going to the automotive industry, Paragon must insist upon quality. 'Prodag' helps to maintain this standard. These parts for convertible automobile tops are precision-molded from both 355 and 319 aluminum alloy. Molds are preheated before each day's run to 600°F and the casting cycle maintains this temperature. The 'Prodag' dilution ratio is 1 to 4 parts water and is applied to the molds with a commercial spray gun. Aside from occasional touchup at points of greatest wear, this coating lasts through the entire run. Because of the physical contours involved in these comparatively small, light castings, they require rapid cooling in certain areas to insure uniform strength. The 'Prodag' coating — with its proven fast heat transfer ability — allows the castings to cool without breaks or pinholes. And by parting more easily, the high-finish castings which result have given Paragon Aluminum products wide acceptance in this demanding industry.

Typical parts cast at Paragon Aluminum include these automobile convertible top braces. More uniform strength, better finish, and fewer rejects result from this company's use of Acheson 'Prodag'.

If you have a metal casting problem, call in your Acheson Service Engineer. Or if you prefer, write direct for additional information contained in our Bulletin No. 425. Address Dept. MP-4.

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Colloidal graphite increases die life because of its stability at high temperatures, excellent lubricating qualities, and its ability to prevent adhesion and the scrubbing effect of hot metal. This cannot be said of conventional petroleum compounds which either decompose rapidly at temperatures above 300°F or do not possess the required lubricity necessary under good die casting procedures. It will not volatilize when in contact with the hot metal and cause pock marks due to gas formation. It will perform when present in extremely thin films which will not affect dimensions or cause discoloration of the parts being cast. And since it does not volatilize or otherwise be destroyed in the casting process, it does not need to be applied as often as other lubricants. This fact alone has often increased production as much as 25%. Investigate the use of an Acheson colloidal dispersion in solving your die casting problem . . . *It probably is the very answer you need.*

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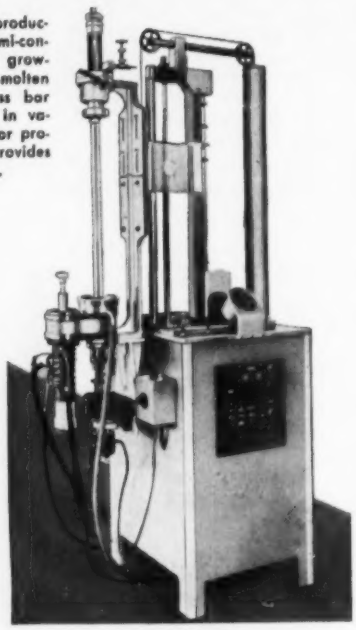

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Metal Powders . . .

Dispersion mixtures are usually extruded in cans; if cladding is required on the finished product (it usually is), the can is not removed, but forms the clad.

Dispersion control materials consist of dispersions of elements or compounds of high absorption cross section for thermal neutrons – boron, cadmium and the rare earths are examples – in suitable matrix materials such as stainless steel, zirconium or aluminum.

Like the dispersion-type fuel elements, their properties are less affected by irradiation than are those of alloys made by conventional means. Furthermore, a much larger range of material combinations can be made by the dispersion method. Perhaps the most outstanding characteristic of these materials is the extremely uniform distribution of the dispersed phase. Up to now, the dispersion-type control materials made by conventional processes involving a liquid phase have not shown the homogeneity regularly found in powder metallurgy products. Since uniformity of composition is important in many control and burnable poison materials, these powder products could be very useful indeed.

In the manufacture of nuclear materials, powder extrusion techniques are perhaps in their most advanced stage. One example is the fabrication of clad stainless steel-rare earth oxide combinations in complex sections by extruding through a circular orifice. As described in *Metal Progress* (September 1957), this is done by canning flat compacts of the stainless steel-oxide combinations, and assembling them with soft steel inserts to fill a sealed sheath. This assembly is extruded, and then the soft steel inserts are dissolved in acid to leave the required stainless clad rod.

High-Temperature Materials– There is much interest in ways to introduce dispersion-type strengthening into refractory-base metals and alloys. Many of these form oxides which are relatively unstable in service. Since we cannot rely on metal-oxide films as with aluminum and magnesium, other methods have to be considered. The method most frequently used is quite simple.

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Users of MEL-TROL high temperature alloys report they are the cleanest forging alloys of their type. Their performance in service is consistently good. It minimizes the variations in service life found in conventional alloys.

It's the result of the finest quality control tools and procedures known today used together with a new, *Carpenter*-patented mold which produces ingots with the highest uniformity yet achieved in commercial steelmaking.

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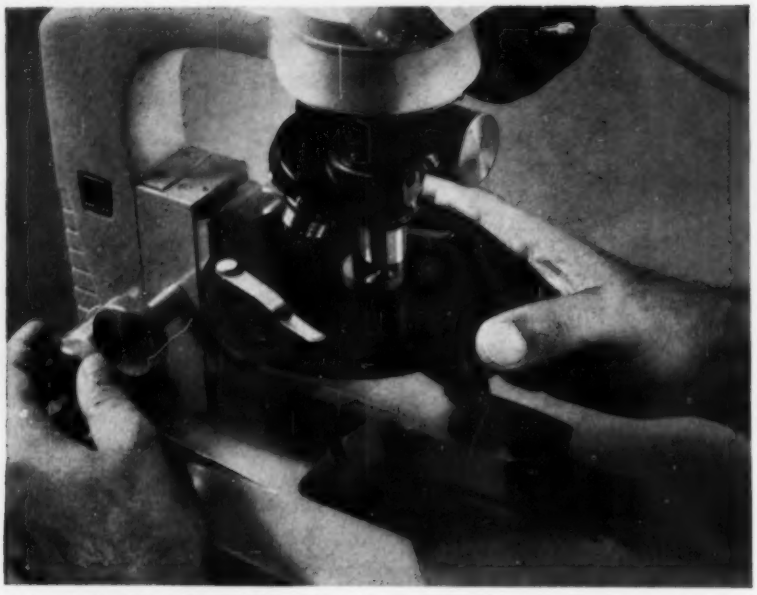

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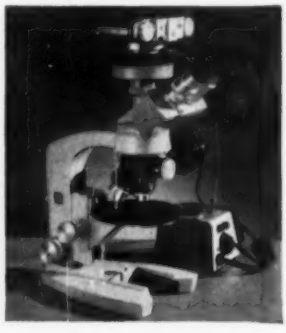

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Metal Powders . . .

The stable hard phase is mechanically mixed with a suitable refractory matrix; this mixture is pressed, sintered and extruded.

Copper and nickel with various oxides, and nickel-chromium and cobalt alloys with oxides, carbides and borides have been investigated. In these groups, improvement in high-temperature properties is thought to result from thorough dispersal of fine particles of a stable hard phase. This prevents plastic deformation at high temperatures. However, strengthening gained by mechanically adding the hard phase has often not been as great as that obtained in SAP-type materials. In part, this may be because suitable powders are not available in particle sizes that are small enough. Also, blending techniques can stand improvement. At the present time, considerable work is being carried out on various systems, and considerable emphasis is being placed on new methods of satisfactorily dispersing the hard phase.

In handling powders, extrusion is capable of making, in relatively large sections, a range of materials exhibiting unique properties. Also products of hydrometallurgical extraction can be consolidated without melting. So far, the technique has been used principally in research and development; the future will decide whether this method can be used economically.

Molybdenum Welding

Digest of "Inert-Gas-Shielded Consumable Electrode Welding of Molybdenum", by N. E. Weare, R. E. Monroe and D. C. Martin, *Welding Research Supplement*, Vol. 37, March 1958, p. 117-124s.

MOLYBDENUM is handicapped by its low ductility, particularly in weldments, at room temperature. Inert-gas-shielded tungsten-arc weldments have limited ductility because of large grain size in the weld metal. Using a consumable electrode produces a smaller weld-metal grain size and a narrower heat-affected zone and consequently improves the ductility. But this introduces additional problems of arc stability and

On Highway Trailer's *assembly line, Yoloy "E" side panels are being set in place—will provide a higher and wider trailer interior for carrying maximum payloads.*

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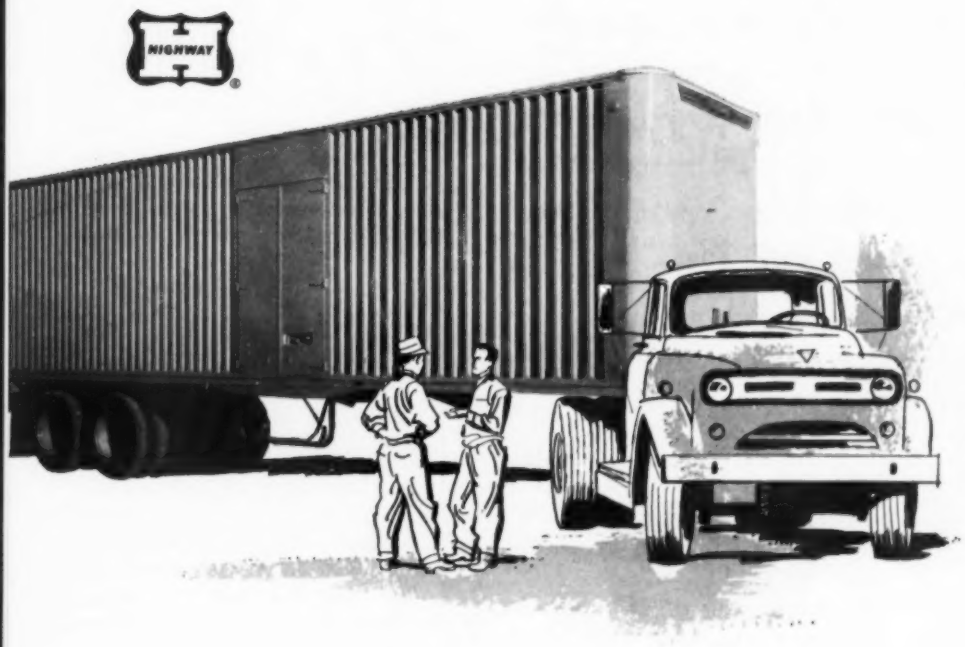
Youngstown Yoloy "E" high-strength steel



Design of this beautiful, new Highway Freightmaster fulfills the need for extra strength and rugged durability to handle the biggest, toughest loads—*with no loss in cubage!*

Helping Highway Trailer Company of Edgerton, Wisconsin achieve this new standard of rugged strength and durability in their complete line is Youngstown Yoloy "E" high-strength steel sheets. They report, "Weight saving of 25% is realized because Yoloy 'E' provides much higher tensile strength than carbon steel. Also, its resistance to atmospheric corrosion is ideal for all-season trailer service."

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Mo Welding . . .

metal transfer, studies of which were initiated by the authors.

Reverse polarity (electrode positive) studies indicate that molybdenum oxide on the metal surface tends to stabilize the arc. Oxygen in particular, however, is highly detrimental to ductility in molybdenum and other methods are required for arc stabilization while welding cleaned sheet. The arc is not stable when welding cleaned sheet with either polarity unless the cathode is coated with an electron emitting compound, for example, cesium chloride. These coatings are more effective on the electrode (straight polarity) than on the work (reverse polarity). Further study of this is needed.

Good metal transfer is of spray type (rather than drop type), occuring in the inner cone of the arc, with no spatter. Appreciably higher current densities (300,000 to 400,000 amp. per sq.in. with 0.040-in. diameter electrode) than normal steel practice were used with molybdenum (reverse polarity in helium) to produce spray-type metal transfer. Some spatter was observed indicating even higher currents would be optimum. Arc stability also increases with current density. Current density does not appear to have a great effect on arc stability and metal transfer for straight polarity.

Cracking can develop from longitudinal shrinkage stresses in the weld. Cracks are usually transverse to the weld and run through a defect which causes a stress concentration or reduced section. Less cracking is observed with straight polarity. Further improvement might be realized using preheat-postheat cycles.

Porosity is not a major problem with a stable arc, good metal transfer and adequate shielding.

Limited work indicates inert-gas-shielded consumable-electrode welding may be best applied to welding thick molybdenum plate, with the tungsten-arc method better for sheet up to ⅛ in. thick.

Arc stability and metal transfer were improved most with direct current, straight polarity, helium-shielded consumable electrodes coated with electron emitting compounds using high-current densities.

C. O. SMITH

Metal Progress

Bulletin Board...

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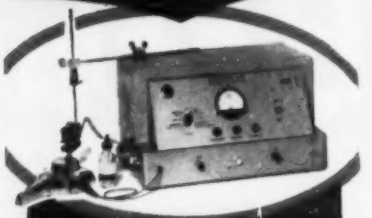

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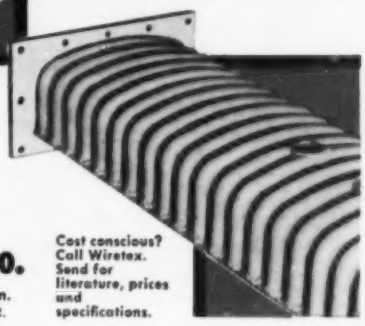
...last longer, lower costs!



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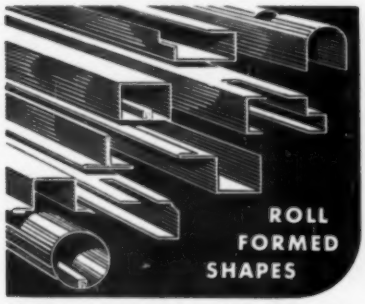

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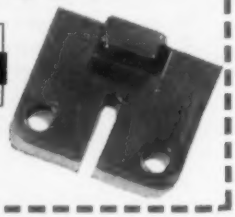

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- Transverse Bars
- Green Strength
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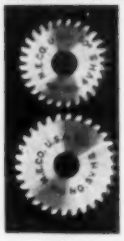

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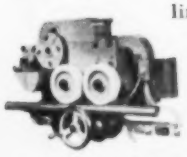

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RODS ¼" dia. to 6½" dia.
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SORGEL reactors are designed to meet your exact requirements. Let us know what your problems and requirements are, and we will submit our recommendations with complete information.

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All standard and intermediate ratings, ½ Kva to 10,000 Kva, 120 to 15,000 volts.

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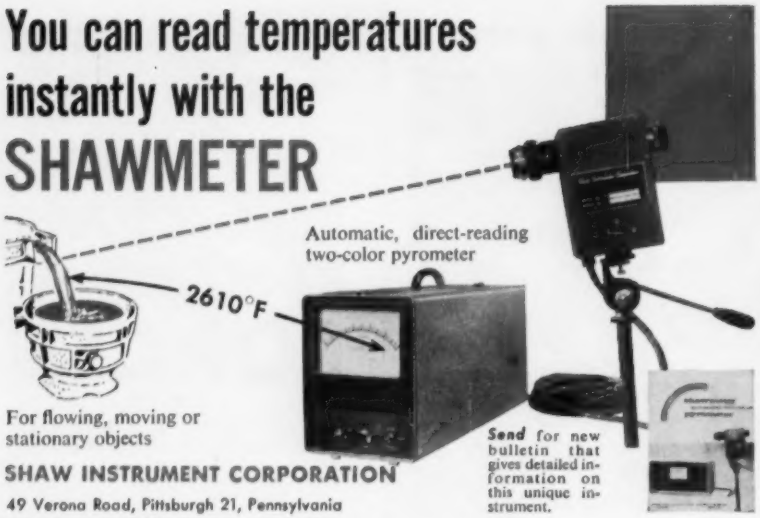

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FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
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STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available.

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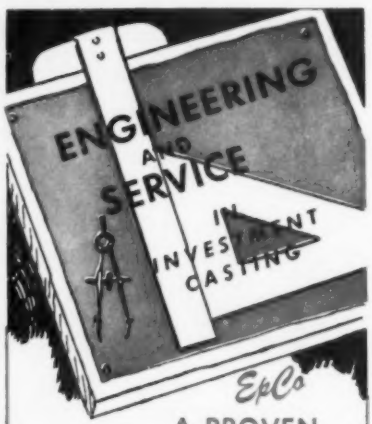

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SINCE 1922

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KNOOP

VICKERS

Applies 1 to 10,000 gram loads

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Kent Cliff Laboratories Div.

The Torsion Balance Company

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low temperature equipment

to 140° below zero

for

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- seasoning gauges
- precision tools
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Solve

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Sorting
Demagnetizing
Problems

with

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

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- Easy to operate—change from "Rockwell" to "Rockwell" superficial testing in seconds
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Wilson Mechanical Instrument Division

American Chain & Cable Company, Inc.

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ACCO

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New

- RELIABLE
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- REALLY PORTABLE
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Complete with Magnifying Glass Test Blocks Carrying Case

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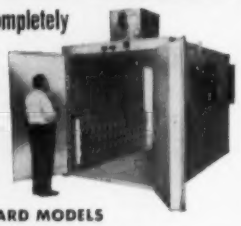

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CHICAGO 7, ILL.

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LUCIFER FORCED AIR FURNACE

The Lucifer Furnaces, Inc., Series 4055 furnaces are manufactured in ten standard models with 800° F. or 1250° F. maximum operating temperatures. These furnaces are designed for tempering, drawing, heat treating aluminum, and glass annealing. Each furnace is a complete unit . . . controls included. They are equipped with a large fan and motor to force circulation of air in the working chamber to insure maximum uniformity of temperature.

All electric heat treating furnaces by Lucifer feature • low initial cost • low upkeep • top production performance • minimum replacement downtime. For free engineering advice, parts, or product information . . . write, wire or call . . .

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How to Cut Pot Costs:

Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

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Eclipse PRESSED STEEL POTS

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A Complete Line of
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WELDING STAINLESS?

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Whitey knows the ropes when it comes to welding stainless . . . and he's happy to help with your welding operations. His years of experience, plus the trusted welding materials of Maurath, add up to a guarantee of quality welding. Call Maurath for stainless and heat resistant arc welding electrodes of all analyses . . . coated, straightened . . . cut . . . coiled and spooled.

Quality Is Remembered Long After Price Is Forgotten

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FREE

the QUENZINE STORY

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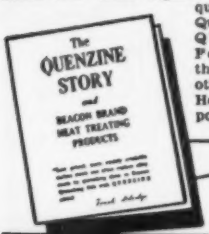

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LIST NO. 29 ON INFO-COUPON PAGE 170

other extruders said it couldn't be done . . .

GENERAL DID IT!

The manufacturer of heaters wanted a hearth bottom — a fluted, gold-anodized aluminum extrusion. Specifications called for a 7" x .050" shape. Extruders with presses that take 8" diameter billets said it couldn't be done because of the thinness, too great a reduction ratio.

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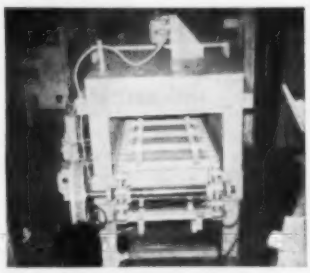
GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!

LIKE-NEW MORRISON CONTINUOUS CHAIN BELT TEMPERING AND STRESS RELIEVING OVEN



Working Dimensions: 30" w x 160" l x 13" h Calrod heated for 850° F, 440 volts, 60 kw. Circulating Fan in Roof, Complete.

Also:

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DETROIT 11, MICHIGAN

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make hardness tests ANYWHERE WITH THE **NEWAGE TESTER**

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
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STANWOOD HEAT TREATING S EQUIPMENT **RETORTS and STACKING BASKETS**

REPRESENTATIVES IN PRINCIPAL CITIES

of new Cor-Wel construction give you:

- Lighter weight—yet stronger
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- Basket grid, grid supporting ring and top ring are of high temperature cast alloy
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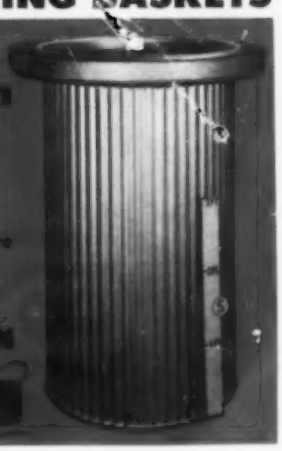

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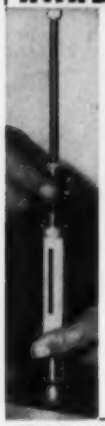
Portable and Precise
HARDNESS TESTER

Model ST-5



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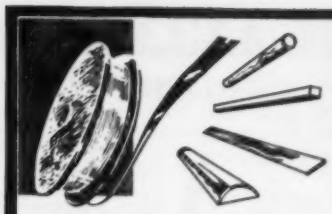

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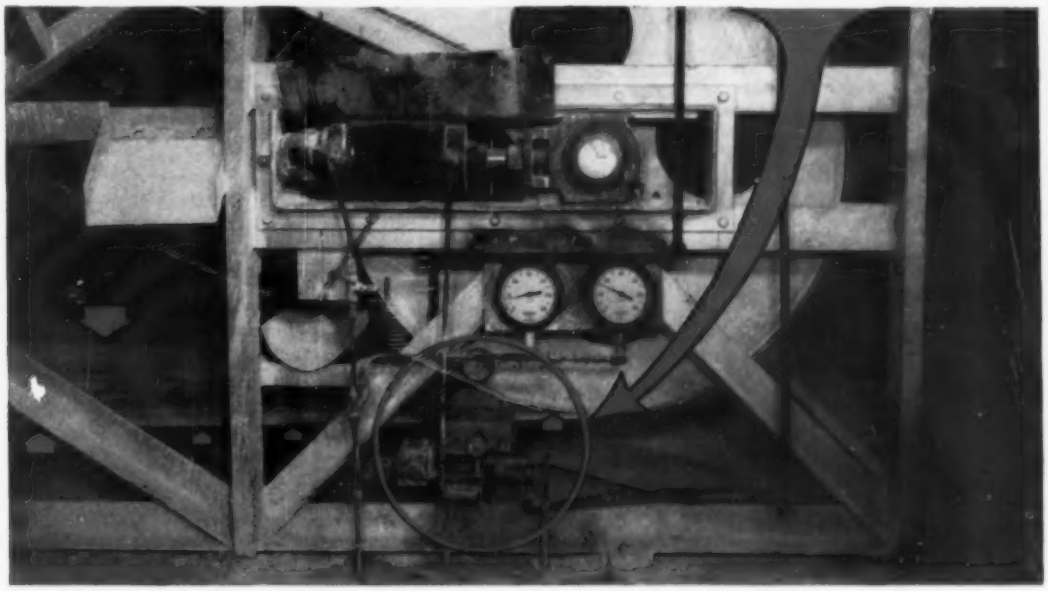
A producer of ceramic products was experiencing torn and distorted belt edges like this on its conveyor type slurry dryers. The heat needed for rapid drying made frequent adjustments necessary to maintain correct tension and alignment of this stainless steel belt...



...now this plant uses North American Hydraulic Controls to maintain the smooth straight edges shown in this unretouched photo. A single North American Regulator continuously maintains true belt tracking while holding a constant tension on the belt despite stretching or contraction. Even an operator who is a perfectionist cannot match the perfect job done by North American's automatic controller which constantly senses and corrects for extremely small irregularities.

You too can SAVE MONEY

SAVE on belt replacement costs—longer belt life
SAVE on belt maintenance costs—reduced repairs
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Call your nearby North American engineer or write for bulletin 2-001

NORTH AMERICAN for COMBUSTION and Hydraulic Controls

The North American Mfg. Co.
Cleveland 5, Ohio

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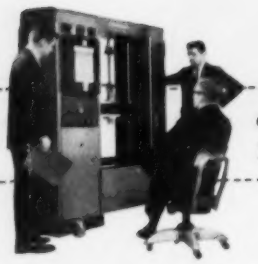

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Twinning in Face-centered Cubic Metal

Recent studies of the deformation characteristics of copper single crystals at 4.2°K and 77.3°K were made on the Instron Universal Tester equipped for low temperature testing.

Special x-ray techniques were used to examine the tested samples . . . one of the results: *mechanical twinning in face-centered cubic metal.*

This heretofore unproven fact is verified in a 10-page, illustrated article on the testing of copper single crystals which is now available to you. Write for bulletin M-2 . . . it is one of many technical articles covering all fields of testing now ready for you in reprint form.

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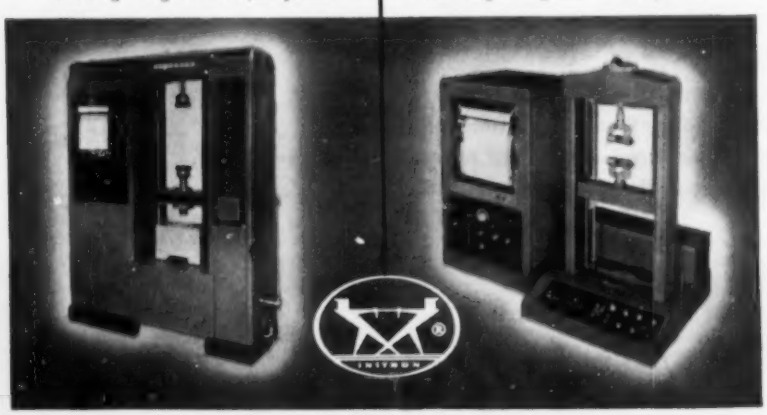

Spectrochemical Analysis Using the Quantovac

Digest of "The Quantovac—a Direct Reading Instrument for the Control of Carbon, Phosphorus, Sulphur, and other Important Elements in Iron and Steel", by H. W. Clakins and M. F. Hasler. Paper presented at Electric Furnace Steel Conference, Pittsburgh, December 1957.

EXPERIENCE has shown that the analysis of the few elements that cannot be handled by optical emission methods costs much more than the analysis of the 10 or 20 that may be handled on direct-reading instruments. This has led to a search for means to extend direct-reading analysis to include additional elements beyond the 70 or more now analyzed in groups with conventional excitation sources and conventional direct-reading instruments.

Two promising ways to extend this means of analysis are by changes in the means of sample excitation and by extension of the spectral range into other regions of the spectrum. The Quantovac is the result of a three-year development project of the Applied Research Laboratories in Lausanne, Switzerland, where this instrument is now in production. The instrument is designed to extend the spectrum range available for useful, high-speed spectrochemical analysis into the far ultraviolet. The all-important, most sensitive arc lines of carbon, phosphorus, sulphur, mercury, arsenic and selenium lie in this region as well as the most sensitive spark lines of antimony, germanium, helium, aluminum, lead, gold, platinum, silicon and bismuth.

Actually, in designing the Quantovac as a practical instrument for the spectrochemist, three separate problems exist in operation of spectrometers below 1900 Å: First, a simple, high-speed means of introducing samples to the instrument must be provided; second, excitation conditions close to optimum must be available if the inherent sensitivity of the spectrochemical method is to be utilized; and, third, optical paths in the instrument must have the necessary transparency for the radiations of interest.

The first and second problems are solved by using tank nitrogen which

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HOLO-KROME features socket screw products having toughness as well as uniformity of hardness and strength. AGF Furnace equipment contributes to this high standard.

POSITIVE ASSURANCE that every Holo-Krome socket screw will have correct tensile strength and a uniform distinguishing color, characteristic of quality heat treating, is embodied in the above AGF installation.

This AUTOMATIC production line consists of:

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(2) An AGF Conveyorized Quenching Tank.

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Your heat treating of fasteners or other small parts like stampings, screw machine products and precision castings can be accomplished with greater uniformity and quality control and at lower cost in AGF equipment.

PIONEER Furnace Engineers and experienced metallurgists at AGF will weigh your needs and make a proper recommendation without obligation.

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Testing and Balancing Machines

Chemical Analysis . . .

is transparent at atmospheric pressure. Nitrogen is used to displace the air which enters the arc-spark stand during the introduction of the specimen. Highly transmissive optical paths in the instrument are obtained by using a lithium or calcium fluoride window between the arc stand and the spectrometer, with a vacuum in the main body of the spectrometer and quartz as windows for the multiplier photo-tubes.

The basic instrument is designed around a grating of 24,400 lines per in. and a 1.5 meter radius of curvature which is blazed to favor a relatively small range around 1800 A. The spectrum range is variable by allowing the grating to be positioned at different points along the axis of the tube. For analysis of steel and cast iron, this allows the range from 1650 to 3275 A to be covered in a single instrument. For research on gas analysis, the range from 1100 to 2725 A can be utilized. The major features of the Quantovac are illustrated with photographs of the spectrometer tube, the arc-spark stand and the slit and secondary mirrors. A spectrogram illustrating the sensitivities obtained for the various lines of carbon, sulphur and phosphorus is given. It is pointed out that lines of good sensitivity have finally been made available for the spectrochemical analysis of these elements by going into the far ultraviolet region. D. L. McElroy

Surface Rolling to Increase Fatigue Strength

Digest of "Surface Rolling as a Method of Increasing the Fatigue Strength of Gears", by A. A. Novik and M. S. Balter, *Vestnik Mashinostroyeniya*, No. 10, 1957, p. 65-68; Engineers' Digest, Vol. 18, Dec. 1957, p. 577-578.

THE INVESTIGATION described in this paper is concerned with the driven gear wheel on the bogie axle of a diesel locomotive. The wheel meshes with the pinion of the drive motor. For better wear resistance the teeth of the gear wheel are usually induction hardened 3/32 to 5/32 in. deep. This layer extends around the tooth surface but stops

puts that "want-to-buy" gleam in their eye

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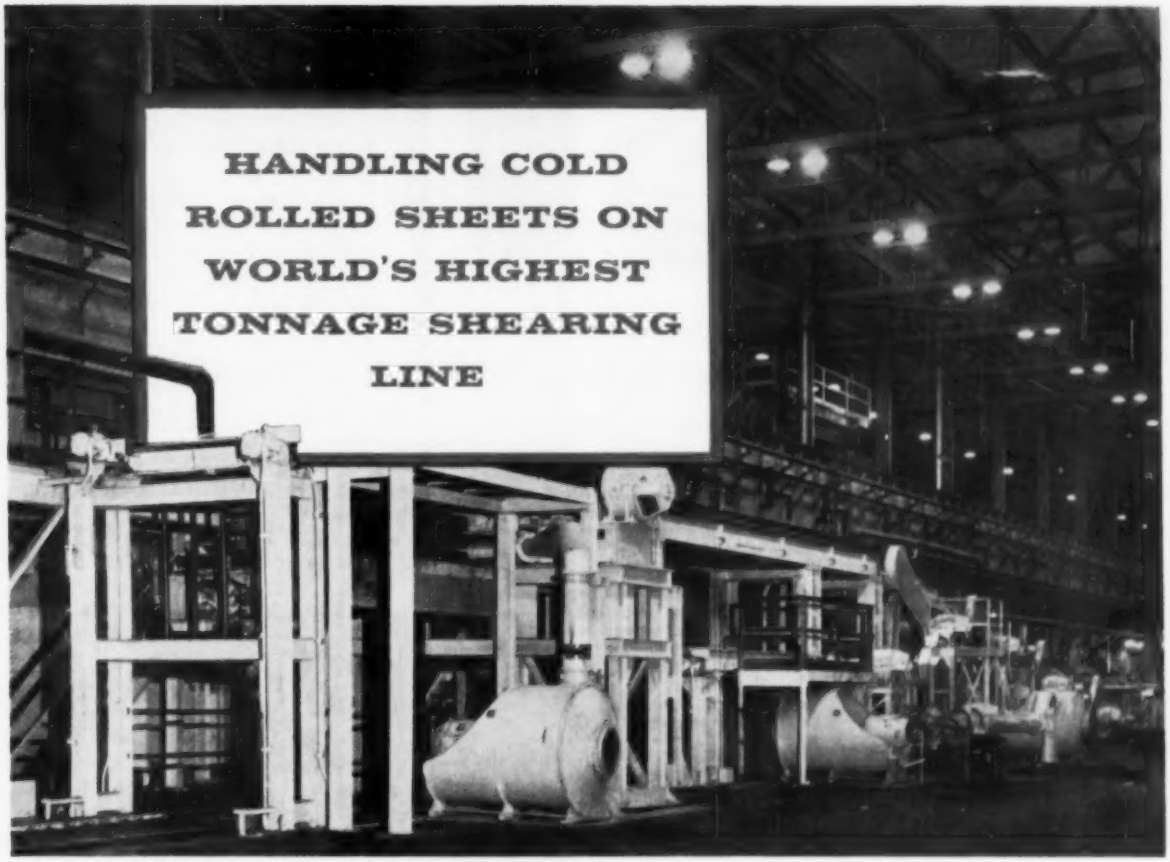
Surface Rolling . . .

approximately 5/32 to 1/4 in. from the bottom fillet. In an actual test run, a locomotive had covered between 32,000 to 62,000 miles when cracks were observed in the root of the gear teeth on the motor side, exhibiting a typical fatigue pattern.

Because the fatigue cracks were situated at the root of the teeth, it was natural to assume that the fatigue strength of the gear could be substantially increased if residual compressive stresses could be introduced in the critical area.

Surface rolling was selected as the desired method to introduce the residual compressive stresses, and a surface rolling machine was promptly designed to the authors' specifications as described in detail in the paper. The roller profile was designed to insure coverage by surface rolling of the entire transition surface between the flank of the tooth and the bottom of the tooth space (the zone of maximum bending stresses). An intermediate zone which was not subject to work hardening developed between the boundary of the induction hardened layer and the edge of the surface-rolled zone. This softer zone did not contain any stress concentration and therefore was not considered detrimental to the intended use. The selected rolling force was 9 to 10 tons which resulted in a residual deformation of about 1/64 in. in the tooth space. Indications of plastic deformation at the sides of the gear teeth were clearly visible.

Fatigue tests were conducted to evaluate the effectiveness of the surface rolling procedure. Most of these tests were carried out on smaller gears made of cast steel blanks, which were similar to those used in the actual production of the driven gears. The reproduced S-N curves show a tremendous improvement in fatigue life due to the surface rolling treatment, but a statistical evaluation of the data is not presented. An S-N curve is shown for equivalently hardened forged steel gears to afford a comparison with the standard cast steel gears. Although the curve for the forged steel gears lies somewhat above the cast steel curve, it is still way below the curve for the cast steel gears with surface rolling treatment, indicating the effectiveness of this treatment. As a result of the re-



Aetna-Standard Sheet Piler at a large eastern steel plant.

SPENCER Blowers "Float" Sheets into Piler Bin

ALSO MANUFACTURERS OF

PNEUMATIC CONVEYING SYSTEMS

INSTALLED VACUUM SYSTEMS

PORTABLE VACUUM CLEANERS

Request Catalog 126C containing complete information on Spencer blowers.

An air "cushion" created by the Spencer blowers permits sheared sheets to "float" down into position . . . reduces surface scratching and speeds production.

Whatever your requirements in dependable air delivery . . . whether for special applications like this or for standard needs in supplying combustion air . . . it will pay to check with SPENCER—first in service to the metalworking industry since 1918.

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Connector Panels T-E has one for your exact needs. These panels provide flexible, centralized control in transferring any number of thermocouples to indicating, multi-point recording and controlling pyrometers. Ideal for patch panel use, they are available in many compact shapes and sizes — with interchangeable plugs and jacks in I-C, C-C, and C-A. A panel for 48 thermocouples and 16 pyrometers measures only 13¼" x 7⅞". Polarity markings and screw-fastened connections make wiring easy.

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Write for Bulletin 23 —H.

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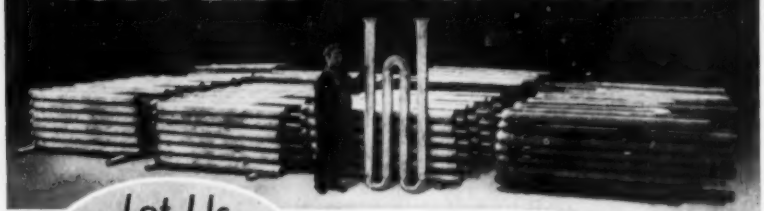

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Surface Rolling . . .

ported investigation, the surface rolling process was introduced into the batch production of gears for diesel electric locomotives. It is reported that in an actual test run on a locomotive travelling 93,000 miles the gear wheels have not shown any signs of fatigue cracks.

F. FORSCHER

Clad Steels for Nuclear Applications

Digest of "Applicability of Clad Steels to Heavy Wall Piping", by J. H. Proctor, Lukens Steel Co., Coatesville, Pa., A.S.M.E. Paper No. 57-NESC-108, March 1957, 7 p.

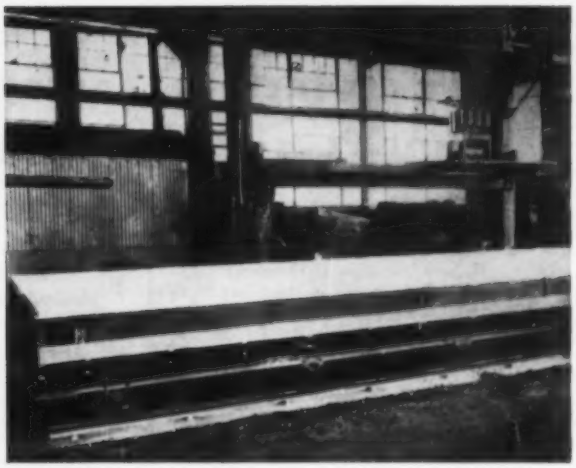
THE QUESTION of economy in nuclear installations is becoming increasingly important and the use of clad steels in which a stainless, nickel, Monel or Inconel cladding is bonded to a carbon or alloy backing steel has obvious attractions. The author reviews the results of initial studies to evaluate the serviceability of clad steels in which the bond is produced during rolling by the combination of heat and pressure.

Typical requirements for fabricated piping and pressure containers were considered to be from 10 in. diameter, ¾ in. gage, up to unlimited diameters and 1½ to 3 in. gage, and of course the composite plate must be weldable. Anticipated maximum service conditions were considered to be a temperature of 650° F. and 2500 psi. pressure.

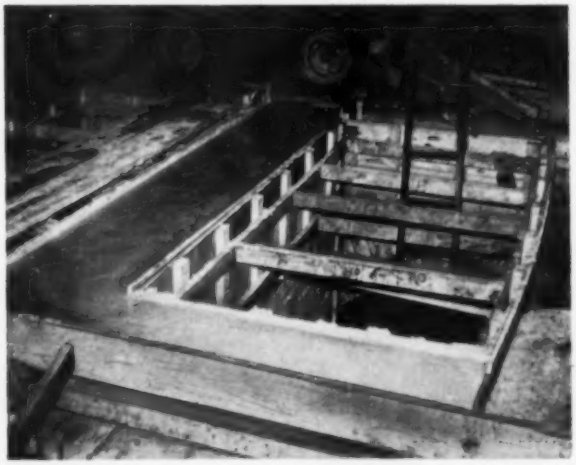
Experiments were conducted on flat plates and cylinders to test the strength of the bond against the stresses caused by the differential expansion of the cladding and the backing material under severe temperature fluctuations. The bond shear strength of flat plate specimens with Type 347 stainless cladding was found to be unaffected after 2000 cycles in which the specimen was water quenched to below 400° F. from an initial temperature of 1100° F.

Other tests on 8-in. diameter, ⅝-in. gage cylinders clad on the inside with Type 304 stainless showed no evidence of failure after 1000 cycles in which the temperature was reduced from 1000 to 200° F. by an

In this stress-relieving furnace, B&W Kaocrete-D is used on the floor ledges, car top, in the door jamb and at the end of the flat roof where it withstands the abrasion of the door. This material is specially designed to withstand severe abrasive conditions and mechanical abuse.



Heavy duty car top service requires a high strength castable. B&W Kaocrete-D is excellently suited for this service at temperatures to 2500 F. B&W Kaocrete-32 is recommended for service above this range.



B&W Kaocrete-32 has been cast to form the curb walls of a soaking pit. When mechanical abuse from ingots damages the curb, Kaocrete-32 has the necessary properties to localize the damage, thus maintaining the serviceability of the rest of the curb.

The castable lining of this aluminum reverberatory furnace must have unusually high strength to withstand the considerable physical abuse of charging, operating and cleaning, while resisting the penetration of the molten metal. Kaocrete-D is widely used in this application.

How B&W refractory castables solve abrasion problems

Refractory castable linings used in metal-working furnaces are often subjected to severe mechanical abuse. Scraping by hand tools, loading and unloading, and the action of the molten metal and particle-laden gases all affect the life of refractories. Among B&W's line of refractory castables are two that are particularly suited to withstand unusual abrasive conditions. They are B&W Kaocrete-D and B&W Kaocrete-32, both of which have been used successfully in many demanding applications.

Send for a copy of B&W Bulletin R-35A. It gives additional information on versatile B&W refractory castables. R604

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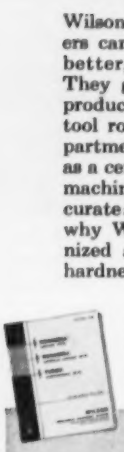

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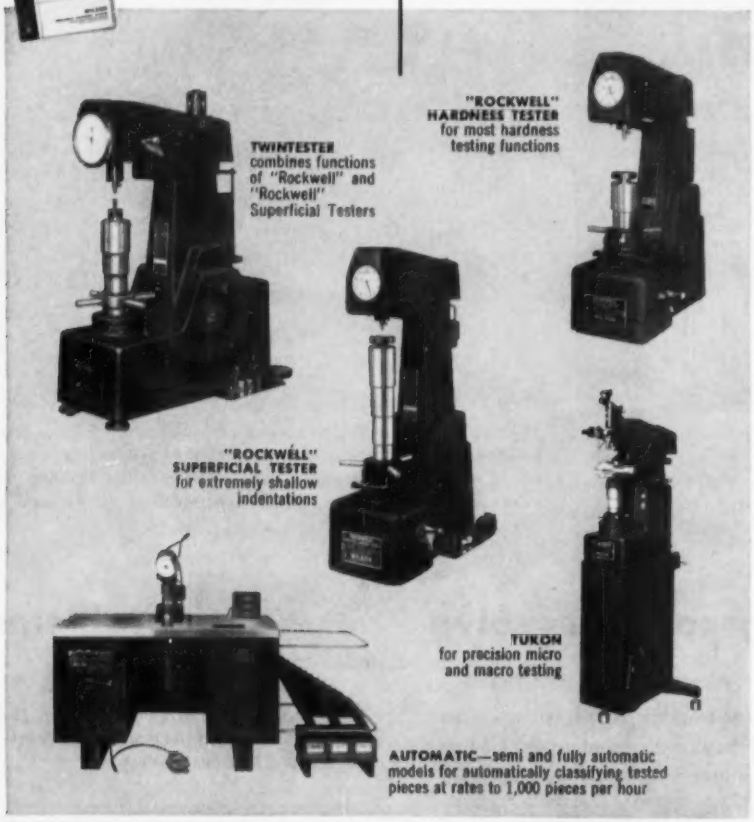
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air blast. Residual stresses were measured by strain gages, using the "boring-out" method on 12-in. diam-

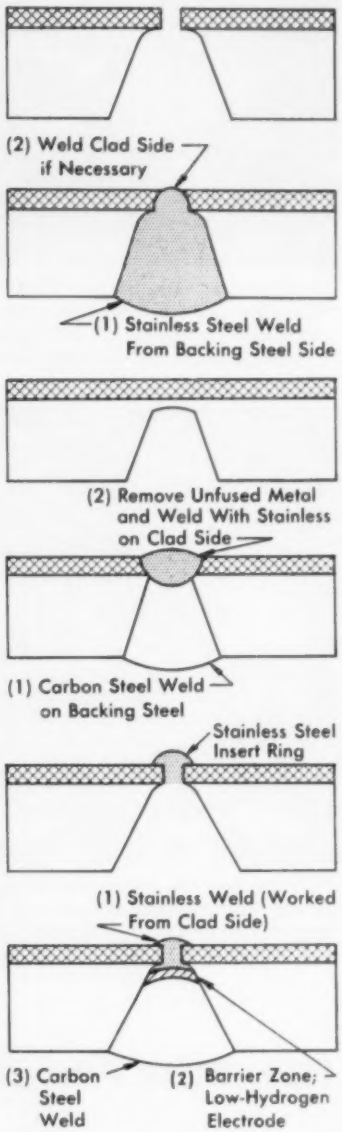
(2) Weld Clad Side if Necessary
(1) Stainless Steel Weld From Backing Steel Side
(2) Remove Unfused Metal and Weld With Stainless on Clad Side
(1) Carbon Steel Weld on Backing Steel
Stainless Steel Insert Ring
(1) Stainless Weld (Worked From Clad Side)
(3) Carbon Steel Weld
(2) Barrier Zone; Low-Hydrogen Electrode

Fig. 1 — Welding Procedures Used to Join Clad Steels: Top —Full Alloy Welding; Center— Combination Welding; Bottom —Reverse Welding Procedure. Welding sequences are shown by numbers in parentheses

eter cylinders, and they agreed with the values calculated from formulas given in the paper.

The increased strength of alloy steel backing plates reduces the re-

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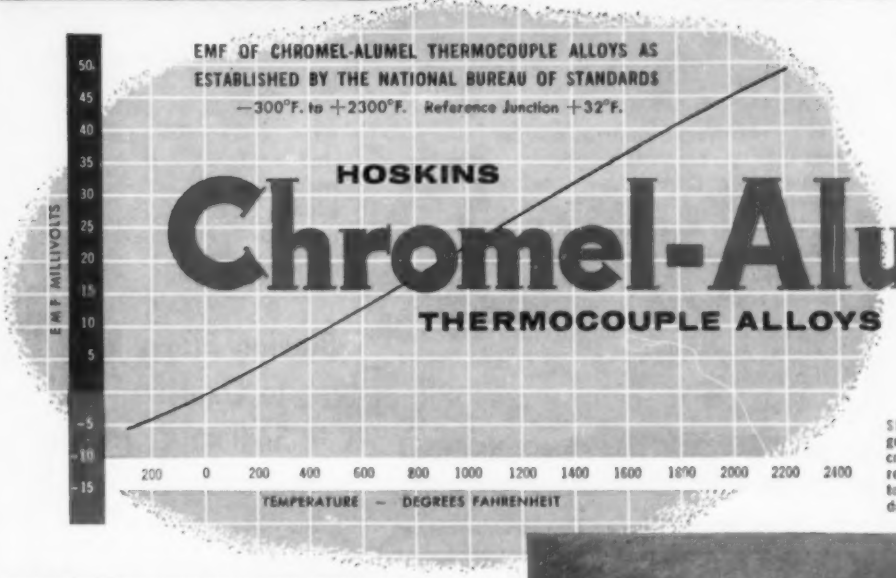

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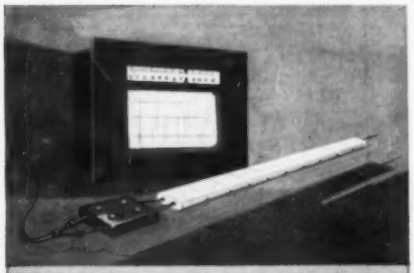

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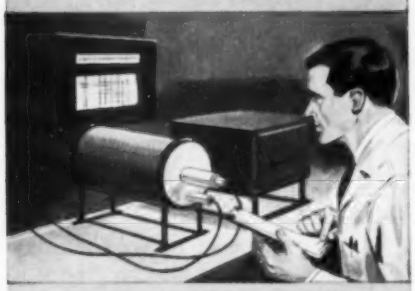

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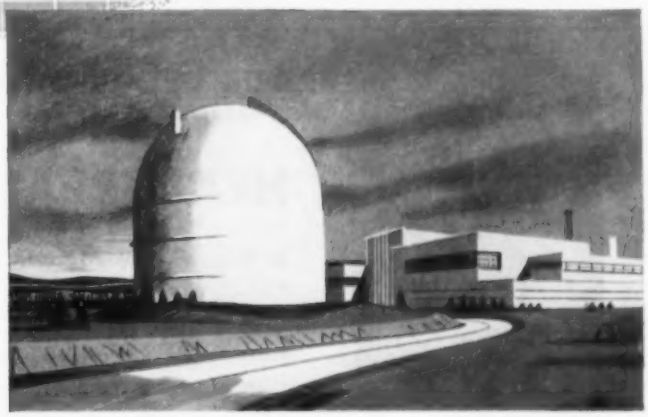

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quired wall thickness sufficiently to make these higher cost backing materials more economical than plain carbon steel in some applications.

The various welding procedures used to join these composite plates are shown in Fig. 1. They include a full alloy weld, an alloy weld on the clad side with a low-alloy backing, and a "reverse" welding procedure in which a stainless steel insert ring is worked from the backing steel side. Various demonstration welds were produced which performed well in cyclic quenching tests and bend tests and, on this basis, it appears that satisfactory production techniques could be developed.

D. G. EBELING

Brazing Alloys Resistant to Oxidation and Sodium Corrosion

Digest of "Sodium Corrosion and Oxidation Resistance of High-Temperature Brazing Alloys", by G. M. Slaughter, C. F. Leitten, Jr., P. Patriarca, E. E. Hoffman and W. D. Manly, *Welding Research Supplement*, Vol. 22, 1957, p. 217-225s.

HIGH-TEMPERATURE BRAZING is replacing welding in many of the intricate parts needed for operation in high-temperature conditions. This paper concerns the oxidation resistance and liquid sodium corrosion of a number of alloys used to braze stainless steel coolant fins to Inconel tubing.

The coolant fin is brazed to the welded seam of the Inconel tubing. The tubing contains liquid sodium. In defective welds, the sodium will seep through and contact the braze metal which covers the weld; thus it is important to obtain braze metal having high sodium resistance.

Many of the commercial and experimental brazing alloys used were made out of nickel, because of its resistance to corrosion and oxidation and because of its good ductility. Pure nickel has a melting point of 2650° F., but brazing alloys used on Inconel or stainless steel should melt below 2200° F. to minimize distortion and grain growth. A search of the equilibrium phase diagrams for

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Robert F. Mehl
Dean of Graduate Studies
Carnegie Institute of Technology

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Brazing Alloys . . .

suitable eutectics and solid solutions of nickel was made. Manganese, phosphorus, tin, boron, silicon, and germanium additions each brought down the melting point. Ternary and quatenary alloys were found to be more suitable than binaries.

No mechanical tests were made on these alloys.

Precious metals were tested because of their known resistance to oxidation, but in preliminary testing, eight of their alloys were badly corroded by liquid sodium; they were eliminated from further testing.

Many of the tests used Inconel as the tube material; however, 13 used Type 304 and 310 stainless steels.

In static sodium corrosion tests, the sample was simply immersed in the liquid metal at 1500° F. for 100 hr. After immersion, the samples were weighed for any change and examined metallographically.

Another test for resistance to liquid sodium used the seesaw method. In it, each sample was prepared by brazing a stainless steel fin to a flat piece of base metal, forming a T-joint. This T-joint specimen was retained in one end of a closed tube made of the same material as the base metal by slightly crimping the tube wall. Liquid sodium was added, partially filling the tube. The tube was then evacuated and sealed by crimping and welding. The sealed tube was rocked like a seesaw by dipping the sample end in and out of the hot zone of a furnace, in controlled cycles, giving the liquid sodium a dynamic action which permitted it to wash back and forth over the specimen. A temperature differential was set up by controlling the time the sample end was in the furnace. This test was more critical than the static one.

The oxidation tests were run in a resistance-wound, box-type furnace using natural convection for air circulation. The samples were T-joints, as described. Tests were run at 1500 and 1700° F. for various times. Some were heated and cooled to room temperature a given number of times to show spalling tendencies. After these tests, the samples were examined with a microscope and evaluated for oxidation resistance.

The authors conclude that these tests are only preliminary, but they

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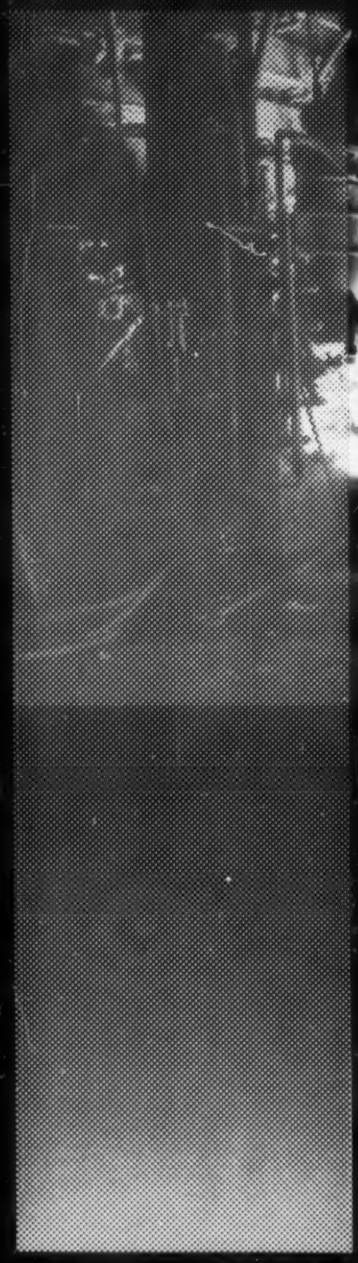
Wean is justly proud of its many years of leadership in tinning line technology: 75% of all electrolytic tin plate produced is the result of Wean's *creative engineering.*

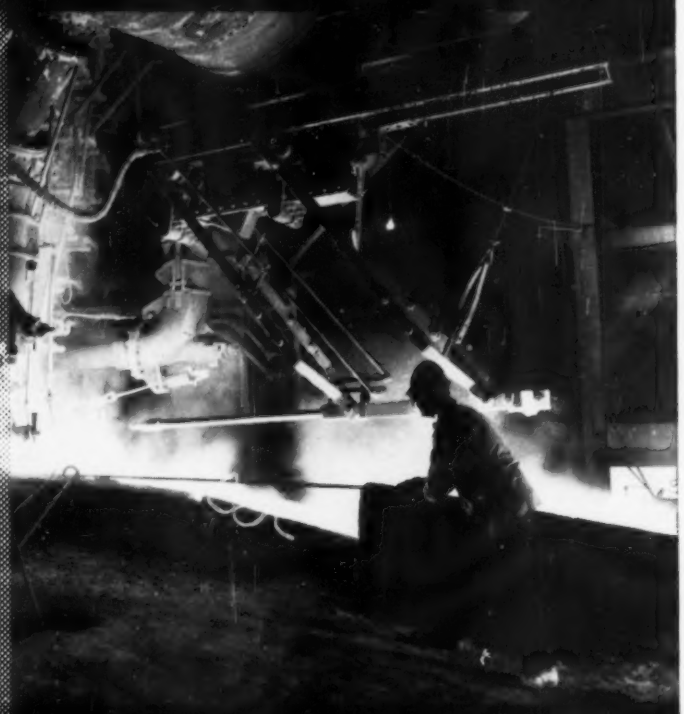
THE WEAN ENGINEERING COMPANY, INC. · WARREN · OHIO

Ansco

Industrial X-ray

best in sight





When more than human vision is needed to evaluate the perfection of critical parts, Ansco X-ray films are looked to as the finest for radiographic flaw detection. That's because Ansco specifically designs its emulsions to record high contrast images of the smallest defects in the toughest samples. If you haven't as yet tried an Ansco industrial x-ray film, why not make a test soon?

Test Ansco's Superay "A", Superay "B", or Superay "C" films on your routine or difficult problems. Notice how the superior readability cuts evaluation time and makes the detection of rejects quicker and surer.

Why not contact your local Ansco representative today and learn, at first hand, how inspection department functions can be speeded up at lower costs! Ansco, Binghamton, N. Y. A Division of General Aniline & Film Corporation.

BRIEFS

on a handy booklet for anyone who buys caustic soda... how to keep arsine out of pickling baths... how to cut degreasing costs... a chemical for electroless nickel plating

Caustic Soda Buyer's Guide offers fast facts

Quick answers to questions on caustic soda abound in this pocket-sized booklet.

You'll find in it basic information on forms and grades, containers and shipping methods.

One section deals with the comparative economics of 50% and 73% liquids solutions. It includes a table and nomograph to help you decide which concentration is the *better* buy for *you*.

Another nomograph helps you estimate instantly how much caustic of a given strength you need to get a given volume of your process solution.

We've also pointed out some factors you might consider when choosing a supplier.

Just clip the coupon for a copy.

How to help keep arsine out of pickling baths

If there is any arsenic in the muriatic acid you use for pickling, it can combine with free hydrogen to form arsine, a dangerous compound to have around.

Arsenic can also be reduced to the metal, leaving spots on the articles you pickle.

All this makes us happy that there is not a bit of arsenic in either of the grades of muriatic acid we sell. In fact, the level of all impurities is quite low. Sulfates check in at a low 0.003% in both our Commercial Grade and Hooker White Grade. There's less than 0.0005% iron in Commercial, less than 0.0001% in Hooker White.

We ship both grades in 18°, 20°, and 22° Baumé solutions in rubber-lined tank cars. Literature will be sent upon coupon request.

Are your degreasing costs too high?

If they are, one reason may be that you have to constantly add new stabilizers to the trichlorethylene you use.

If you are one of those who have to titrate baths frequently and then freshen them up, you may be surprised to learn that there is a trichlor you never have to add stabilizer to—NIALK® TRICHLOR.

NIALK, and only NIALK, has *psp* —permanent STAYING power—in its neutral stabilizer. This stabilizer just does not wear out during normal use. Even after repeated distillation, it's still active, still protecting your trichlorethylene against heat, light, air, moisture, acids, and active metals.

If you'd like to know more about this stable trichlorethylene, send us the coupon.

Electroless nickel plating with $NaH_2PO_2 \cdot H_2O$

There's been a lot of activity of late in the electroless nickel plating of metallic and plastic objects by co-deposition of metals and metallic phosphides.

This probably explains the increased business we're enjoying with our sodium hypophosphite, commercial grade.

Our free-flowing, white, odorless crystals are available in 100- and 325-lb. fiber drums.

Our technical data sheet is offered in the coupon.

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- ☐ Muriatic Acid
- ☐ Trichlorethylene
- ☐ Sodium Hypophosphite

Keep your file current with data on these other Hooker chemicals:

- ☐ Virgo® Descaling Salt
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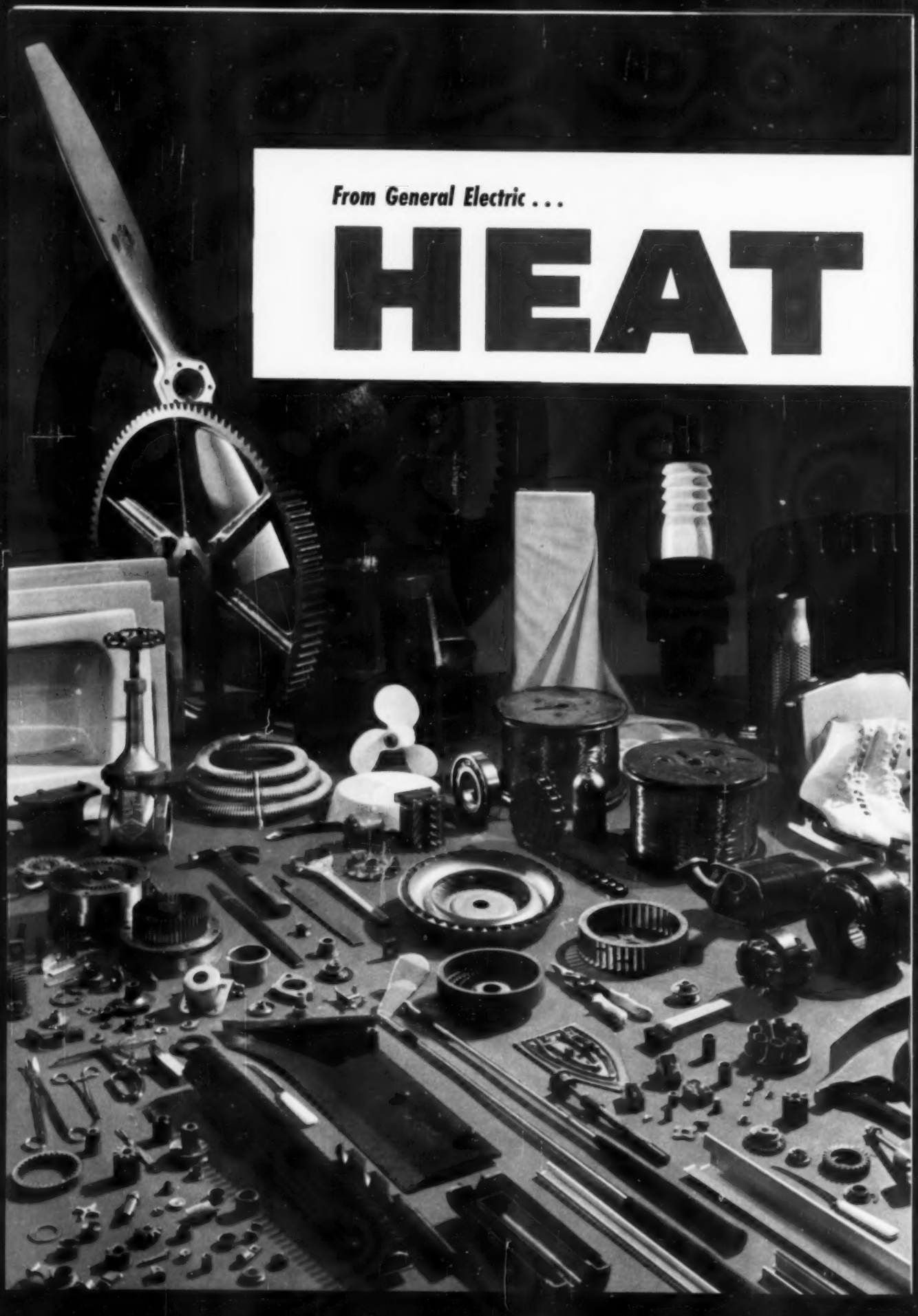

From General Electric . . .
HEAT

CUSTOMER SAVES $45,000 IN ONE YEAR

New General Electric furnace development offers similar savings for other bright stainless steel brazing and heat treatment operations.

General Electric design and engineering skill have produced another significant improvement in the construction of heat processing equipment. Engineering development on the application of high purity refractories eliminated the need for metal muffles for this bright stainless annealing and brazing operation which requires high temperature, low dew point heat treatment.

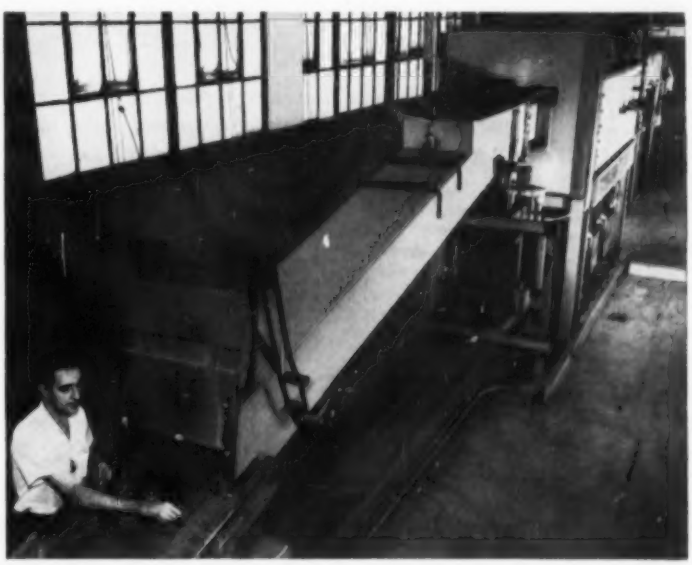
As a result, maintenance and downtime expense for replacing the muffles was eliminated; atmosphere leakage was greatly reduced, and consequently, the customer saved enough to pay the initial cost of the equipment in one year!

This new development, with its significant savings, is equally applicable for other brazing and heat treatment equipment requiring high temperatures and a low dew point. For instance, this design can be adapted to roller hearth, bell, pusher and other furnace types.

Call your G-E Heating Specialist now. He will be pleased to figure your potential savings with new heat processing equipment. The items in the picture at left may offer you ideas on products you process which would be adaptable to General Electric gas-fired or electric furnaces. Contact your nearest General Electric Apparatus Sales Office or write Section 721-22, General Electric Company, Schenectady 5, New York.

The items shown at left are typical of the many products which have benefited from General Electric heat treatment developments—and cost savings often result. For example . . .

Substantial savings resulted when high-purity brick was used in this mesh-belt furnace eliminating the need for costly furnace muffles which require frequent replacement. This is a major technological advance for the furnace industry with today's trend toward higher temperature operation and the need for atmospheres with very high purity. Similar savings can be made for other difficult to treat components which require bright brazing or heat treatment.



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GENERAL ELECTRIC

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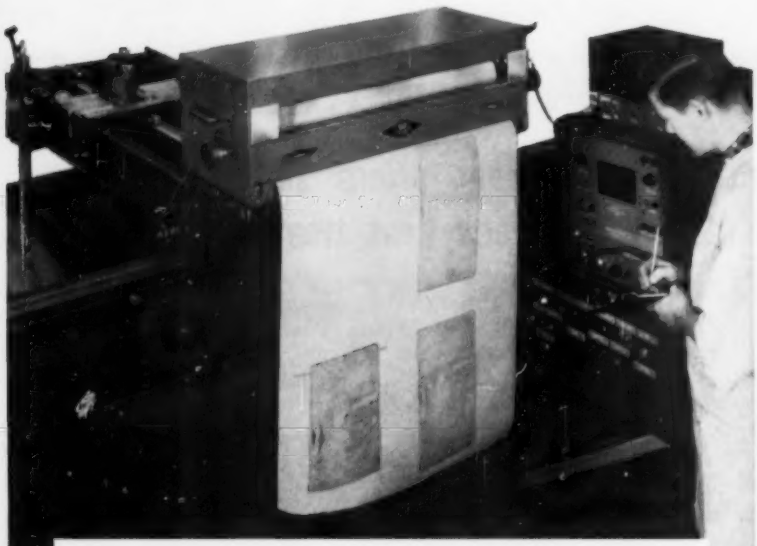

Curtiss-Wright is ultrasonically inspecting honeycomb with successful results. Our technique completely scans panels up to twelve feet wide, achieves high speed and provides an instantaneous permanent record.

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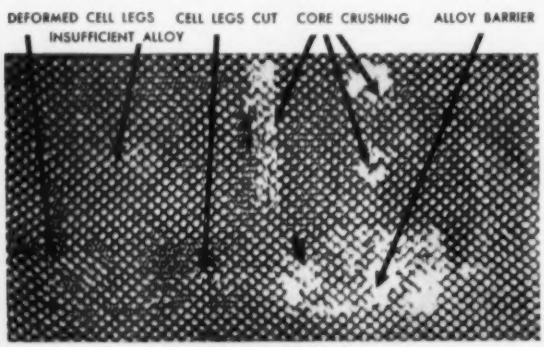

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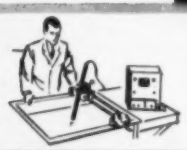

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Brazing Alloys . . .

show that of the alloys included, the Ni-Si-B, the Ni-Cr-Si-B, and the Ni-Cr-Si types are the best brazing alloys for oxidation and sodium corrosion resistance under testing conditions only. W. R. BROWN

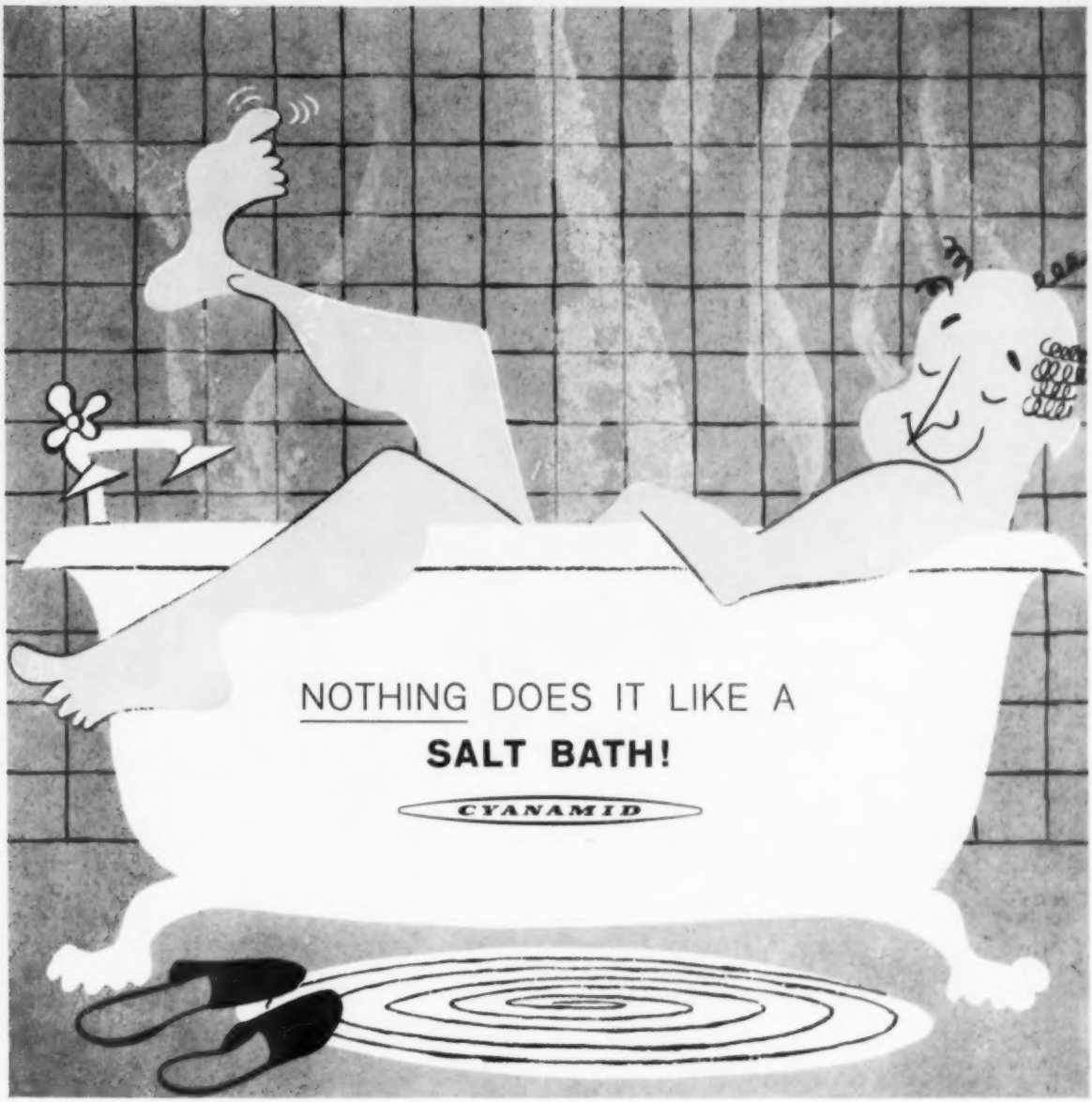
Unusual Stud Welding Application

Digest of "The Application of Stud Welding to Vibrating Wire Strain Gages", by J. C. Chapman, Imperial College of Science and Technology, London. Paper awarded the 1958 Gregory Award during the National Metal Congress, Cleveland, Oct. 28, 1958.

THE VIBRATING WIRE strain gage has been used in several different forms and has a reputation for long-term stability and reliablility. The gage makes use of the variation of the naturel frequency of vibration of a taut wire due to changes in tension. The wire is "plucked" by means of an electromagnet and the same magnet then acts as a pickup to signal the free vibration of the wire to an oscilloscope. A known variable frequency is then matched against the normal frequency of the strain gage wire, and the change of strain in the structure to which the wire is attached is thus inferred.

In principle, therefore, the gage appears to be simple and reliable. In practice, however, the difficulty has been to attach the taut wire to the structure in such a way that the strain in the structure is faithfully transferred to the wire. There must be no relative movement between the wire anchorages and the structure, even when the strain in the structure fluctuates and perhaps alternates between tension and compression. An anchorage movement of a thousandth of an inch, on a 6-in. gage length, falsely indicates a stress change of over 4000 psi.

An earlier wire strain gage, described by R. J. Maidstone (*Engineering*, Vol. 176, 1953, p. 153), anchored the wire to posts screwed to the structure. The screwed-in posts are susceptible to changes in setting as the structure is strained. Furthermore, the effective gage length may vary with each installa-



There are other ways to heat treat metals, but nothing quite compares in *deep-down, over-all, satisfying* results with a Salt Bath.

For one thing, salt furnaces heat work faster and more evenly because temperatures are uniform throughout the bath. Too, salt baths *eliminate* scaling and decarburization without the use of special atmospheres . . . even from bath to quench since a thin protective layer covers the metal. Partial immersion of the work also allows selective heating.

With all of this, initial *costs*, operating costs and maintenance costs are low. Long pot life means less down time; high thermal efficiency means low operating expense. Mechanization saves labor costs, increases production.

Why not check with your *Process Chemicals* salesman and learn of the "engineered advantages" of Cyanamid's highest quality heat treating salts—or drop us a line. Then, put your heat treating, case hardening and carburization jobs into a bath filled with Cyanamid Salts, settle back and enjoy the satisfaction of a job well done.

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These parts were finished without buffing or polishing

Some examples of how the Diversey DS-9 Bright Dip process can solve finishing problems and lower costs. Left, cutaway of welded stainless canteen finished inside and out in a single immersion. Also shown: stainless steel pen points, stainless forgings completely de-scaled, and a stainless plate Bright-Dipped for a lustrous specular finish.

New Diversey DS-9 Bright Dip for 300 Series Stainless Steel

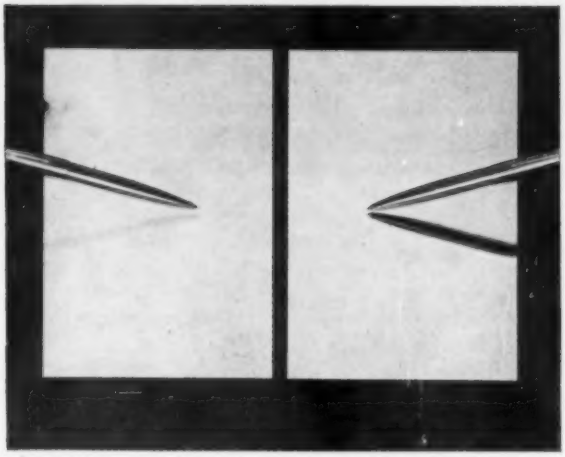
NOW—a specular finish on stainless steel without buffing or polishing!

Diversey introduces a simple immersion process that can mean lower production costs to any stainless steel fabricator. The Diversey DS-9 Bright Dip process has proved conclusively, on the production line, that it can . . .

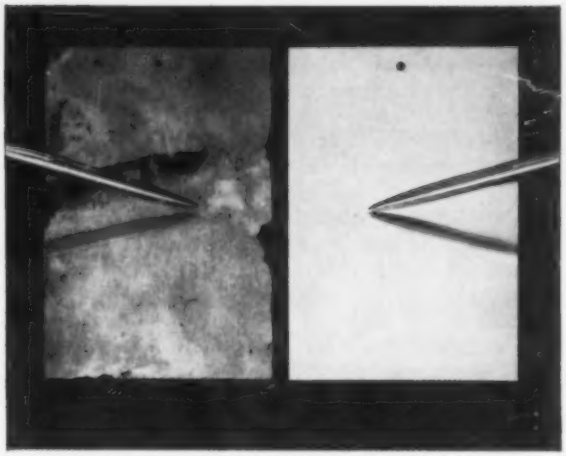
- eliminate buffing, electropolishing or grinding on many parts
- produce a bright, specular finish on stainless steel in the 300 series
- remove scale from stainless steel forgings
- remove weld scale and discoloration
- put a brilliant finish on intricate, hard-to-polish shapes in the 300 series

No electrical current used.

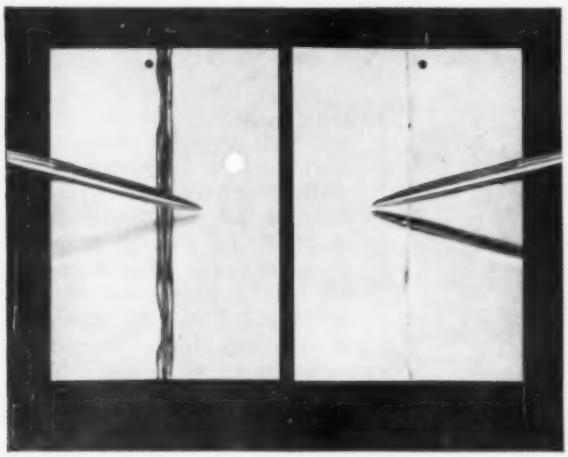
See for yourself how Diversey Bright Dip can save money on your production line



For a specular finish: *Left*, a 302-2B Mill Finish stainless sheet. *Right*, the same steel after immersion in Bright Dip.



To remove scale after heat treating. *Left*, heat treated stainless plate. *Right*, same steel after DS-9 Bright Dip process removed scale.



To remove weld scale from most stainless steel alloys. *Left*, stainless plate with weld seam. *Right*, after DS-9 Bright Dip, showing weld scale completely removed.

To remove scale from forgings of most stainless steel alloys. *Left*, stainless steel forging before and (*right*) after cleaning and finishing in DS-9 Bright Dip.

Try DS-9 Bright Dip in your plant. A trial order of Diversey DS-9 Bright Dip concentrates is available at nominal cost.

If you use stainless steel in the 300 series, it will pay you to get complete information on new Diversey DS-9 Bright Dip. *Write to Metal Industries Department, The Diversey Corporation, 1820 Roscoe Street, Chicago 13, Illinois.*

DIVERSEY.® DS-9 BRIGHT DIP

1820 WEST ROSCOE STREET, CHICAGO 13, ILLINOIS

Stud Welding . . .

tion. In addition, drilling and tapping are tedious operations and may be structurally undesirable.

These shortcomings of an otherwise excellent gage were overcome by stud welding as shown in Fig. 1. The wire is anchored to robust studs which are then monolithic with the structure; the studs are correctly oriented without difficulty. The magnet assembly is mounted from threaded studs below the taut wire, so that the clearance between wire and magnet is easily and exactly adjusted. The gage cover is attached to studs of compatible strength. Each array of six studs is quickly and accurately located by means of a single template (Fig. 2).

The gage posts are ⅝-in. studs, 1¾ in. long. A ⅛-in. slot is milled to accommodate a ½ × ⅛-in. bar to which pressure is applied by an Allen screw. By this means the wire is clamped between the bar and the bottom of the slot. An external lock nut is provided to prevent spreading of the slot by the

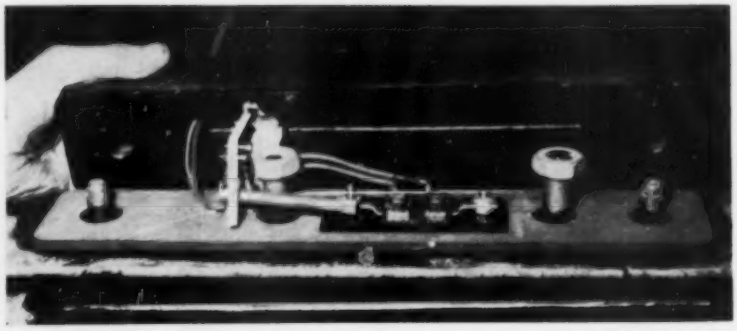


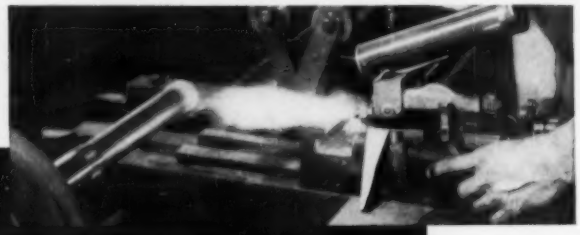
Fig. 1 — Complete Gage With Taut Wire Anchored to Heavy Studs

Allen screw, while at the same time locking the screw and bar. The wire is correctly tensioned with a special wire straining device and then placed between the slots. The wire is then clamped, using constant torque spanners, and finally snipped at its ends to release it from the straining frame. Since the pressure is applied concentrically to the clamping bar, the wire is uniformly clamped across the whole diameter of the stud, so that the free length of the wire is precisely defined.

The gage post stud is correctly aligned with the welding gun by a tongue within the chuck which projects into the slot milled in the post. The gun is aligned with the template by locating the tripod studs in holes in the template, and the gage post stud is driven. The electromagnet is mounted on ¼-in. studs and the cover is fixed to ½-in. studs. By using the same template for locating the six studs, the positions of the electromagnet and the gage cover are correctly fixed in relation to the wire. Welding equipment was type E/3D with rectifier type TRF 6.

The cast iron cover has a compartment which enables the armored cable to be connected to the leads from the electromagnet after the cover has been fixed and sealed. A rubber gasket is provided between the gage cover and the structure; this serves both to seal the cover and to isolate it structurally from the component to which it is attached. There are also rubber washers beneath the cover fixing nuts, and rubber grommets around the fixing stud. D.R.

Fig. 2 — Gun Is Aligned by Means of Template Shown Here



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Deposit efficiency over 90% • Finishing time cut as much as 80%

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The Metco ThermoSpray Gun is light in weight, can be hand-held or machine mounted, requires only oxygen and acetylene for its operation—also sprays ceramics (alumina and zirconia) and other metals in powder form.

Bulletin 139 covers full details, shows typical parts being spray hard-surfaced. It's free for the asking.

The names Metco and ThermoSpray are Reg. U.S. Pat. Off.

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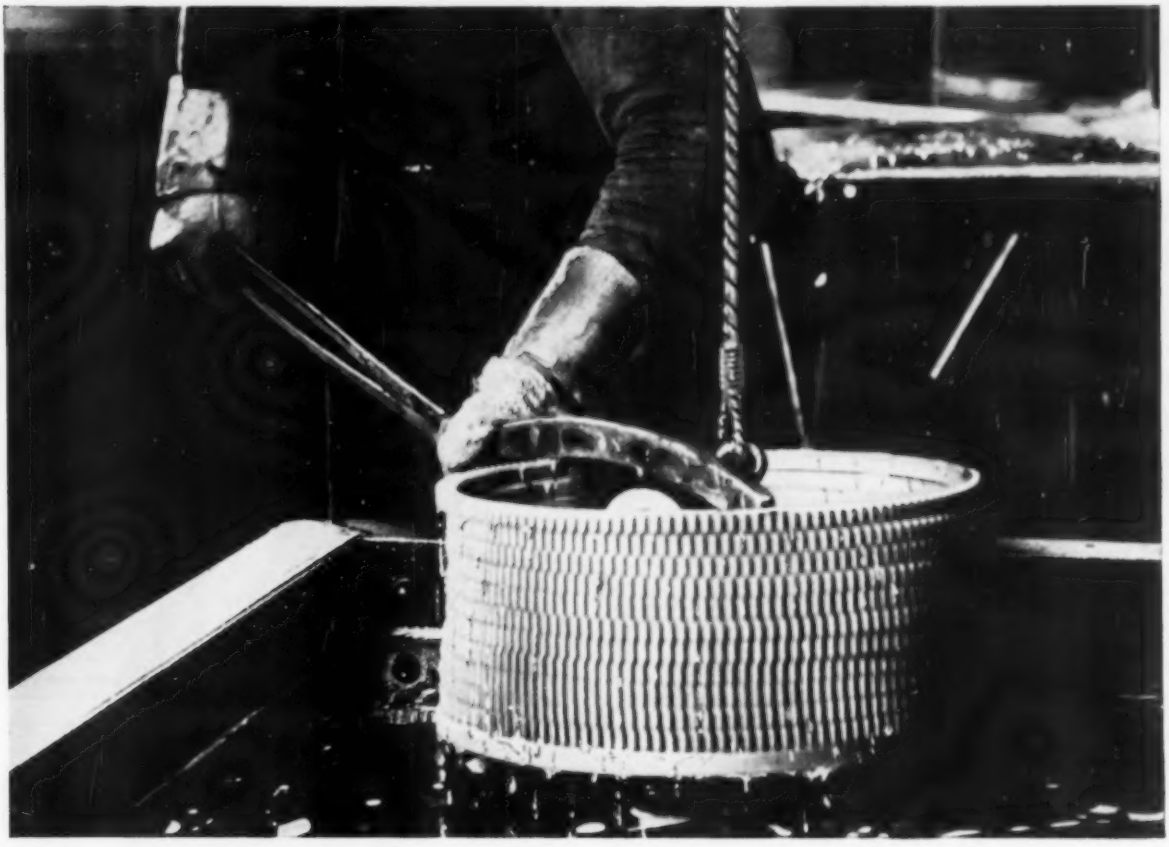

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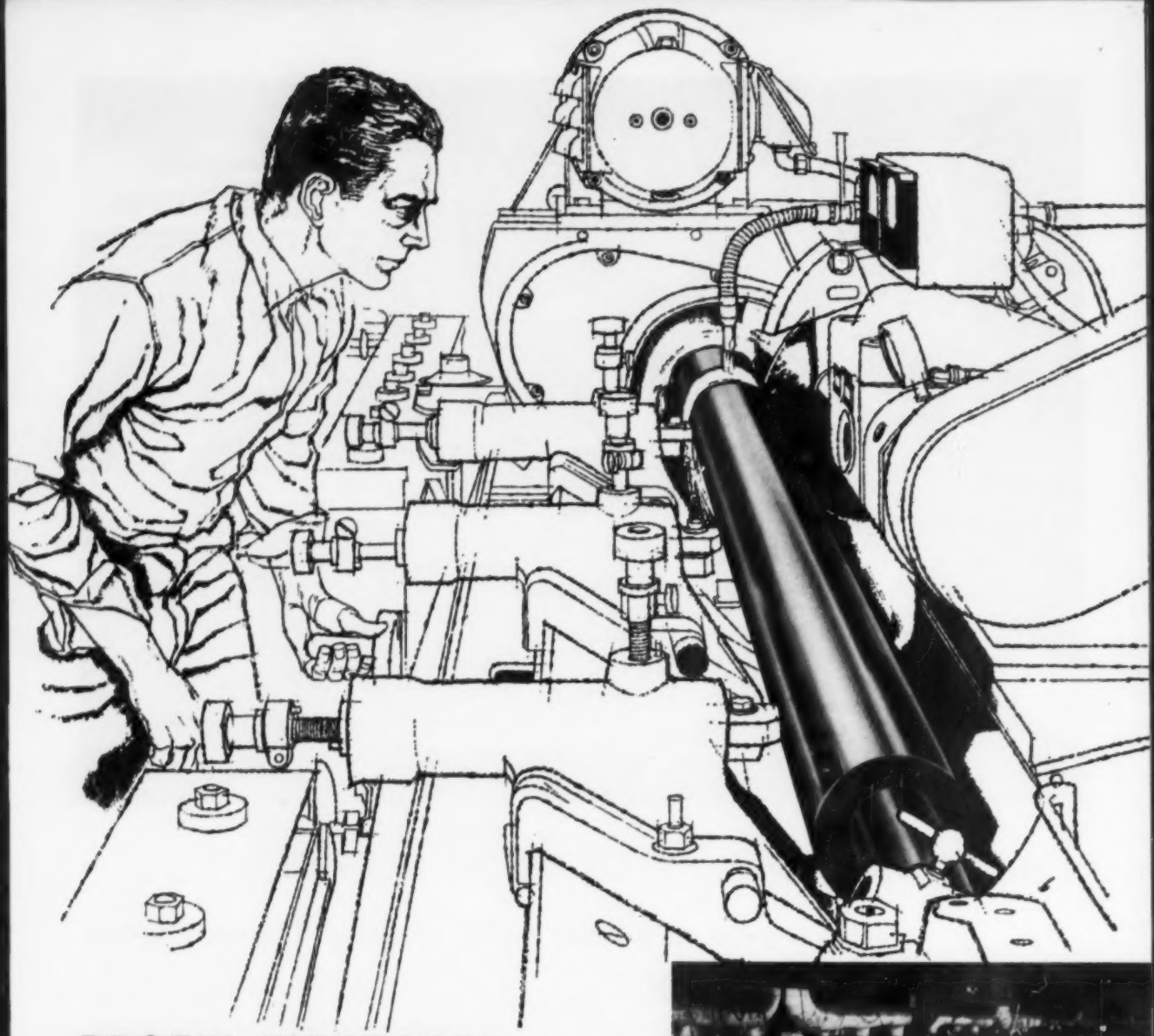

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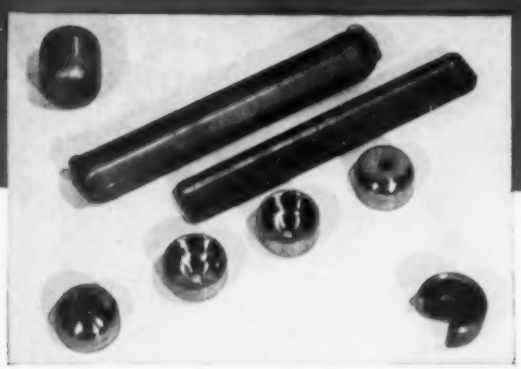
Fansteel Announces the First Space-Age Breakthrough in the Fabrication of Tungsten!



Tungsten! *By Deep Drawing!*

Tungsten! *By Spinning!*

Once again, Fansteel has unlocked the door to unlimited new uses for a valuable metal! Now we have ways to fabricate tungsten into involved shapes heretofore impossible . . . and through such economical processes as spinning, deep drawing, hot extrusion and forging!

Now . . . tungsten—with its melting point of 6152°F., highest of all metals, its terrific strength at high temperatures, its outstanding density of .697 lbs./cu. in.—can be exploited to the fullest. Great advances can now be made in the fields of missiles, nucleonics, aviation, medicine . . . even consumer products. Fansteel has broken through to the secret of fabricating tungsten . . . its potential is now unlimited.

Imagine rocket nozzles with tungsten's fabulous heat/strength properties. Or a tungsten-encased atomic power plant weighing just five pounds. Picture a pure tungsten gyroscope rotor, almost 25% smaller than is now possible, yet retaining complete functional reliability due to its low coefficient of expansion.

Tungsten electronic tube components, tiny wristwatch flywheels and thousands of other applications are now also feasible with Fansteel's tungsten fabrication know-how.

This revolutionary knowledge is so new that we can't supply bulletins, technical information, or other printed data. But our engineers will be glad to cooperate with your own designers and production people in adapting tungsten and these new fabricating techniques to your part or product. Just send print, part samples or call in the Fansteel representative.

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Known for over 50 years as
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This volume contains the outstanding papers presented at the first international symposium on the annealing of low carbon steel held at Case Institute of Technology in Cleveland, 1957. Eleven chapters contain authoritative insight to recent developments in this subject from Russia, Germany, England, Wales, Canada and the United States. The book is published by the Lee Wilson Engineering Company, Inc., and edited by Case Institute of Technology. 138 pages, 8½ x 11, illustrated, blue cloth cover, $7.50.

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This is the story of what metals did to man. It reveals to a sputnik-conscious public the romantic and enchanting discoveries that ushered in today's era of exciting living through better metals. The conversational, sometimes humorous, but always factual format whisks away the reader to 6000 B.C. and then, as if on a metal magic carpet, propels him through the centuries until today's metallurgical "stumpers" are surveyed. This is a book you will enjoy reading, a book that will entertain and inform you. 235 pages, 5½ x 7¾, illustrated, red cloth cover, by Dr. J. Gordon Parr, $2.95.

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This important new book is the most complete collection of scientific and engineering information of what happens to metals in air vehicles and missiles during high-speed flight. The volume is based on the 1957 Albuquerque Conference on Heat Tolerant Metals for Aerodynamic Applications sponsored by the American Society for Metals and the University of New Mexico. It is a book for designers, metallurgists, and specialists in aerodynamics, ceramics and cermets, electronics, heat flow, high temperature properties, lubrication, material procurement, mechanical structures, thermodynamics, protective metallic coatings and vibrations. 432 pages, 6 x 9, illustrated, red cloth cover, $7.50.

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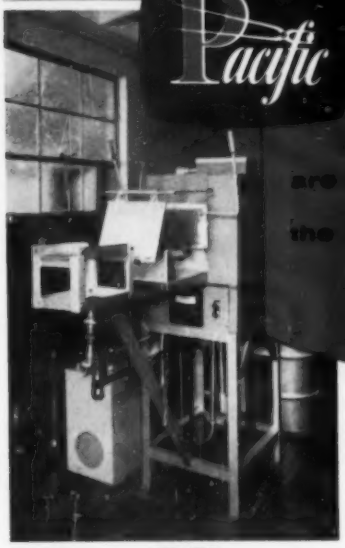

The close tolerances demanded today in the design and manufacture of electronic parts in order to make them smaller and more heat resistant – have called for new concepts in furnace design. Faster handling methods, automatic controls and consistently even heats – have required the design and construction of a wide variety of furnaces to meet the varied and special needs of the electronics industry.

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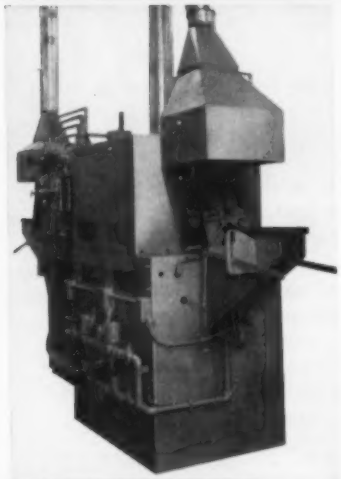
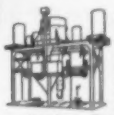


BOX TYPE BRAZING used for medium temperature brazing up to 2100° F. Movable loading rack at front of furnace aligns with furnace hearth during loading and automatically retracts, clearing area for door to close. Has integral atmosphere-tight water-jacketed cooling chamber.



DOUBLE ELEVATOR – for brazing Klystron tubes. In this two station, one furnace system, hydraulic rams alternately raise and lower work into brazing retort and through water-jacketed cooling chamber. Furnace temperatures maintained by multiple zone control system.

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CONVEYOR BRAZING shown here being loaded with wave guide assemblies for silver alloy brazing. Design provides for preheating of parts prior to entering brazing chamber. Multiple zone control for precise temperatures. Suitable for use with atmosphere.

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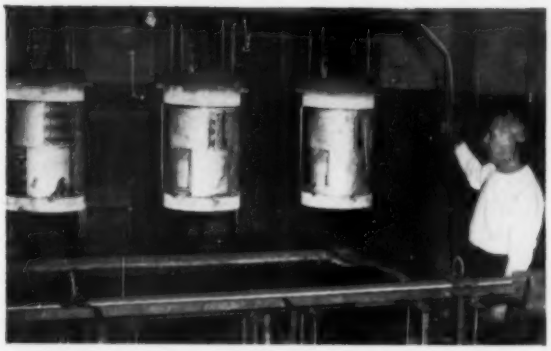
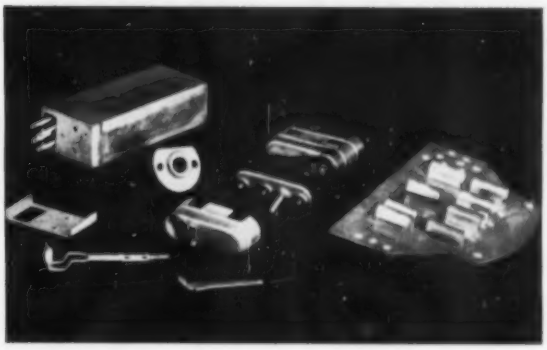


PLATING STEREOTYPES—B&A Nickel Fluoborates build up tough ductile deposits which, in some cases, have enabled stereotypes to run up over 3½ million impressions. They can deposit a nickel face of .0005 inch on the stereotype in 7.5 minute plating cycles . . . providing the high speed operation demanded by the printing industry.



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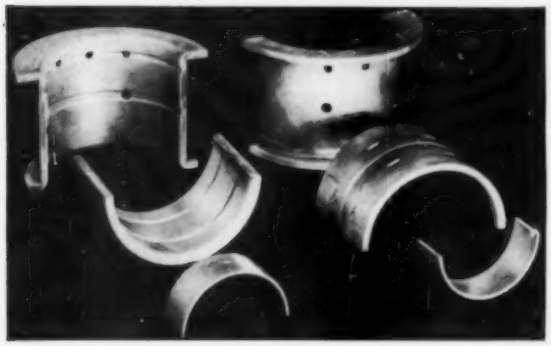

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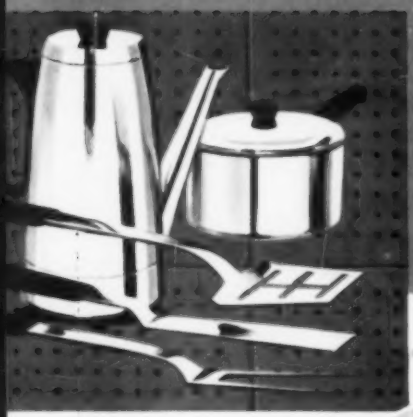

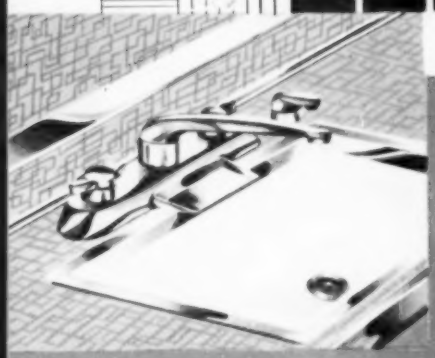

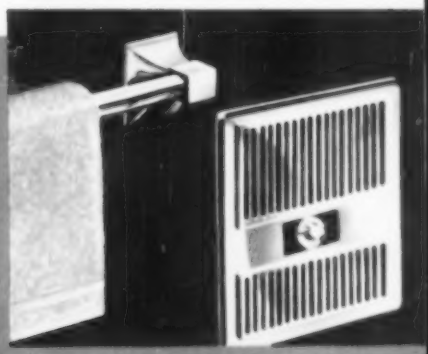

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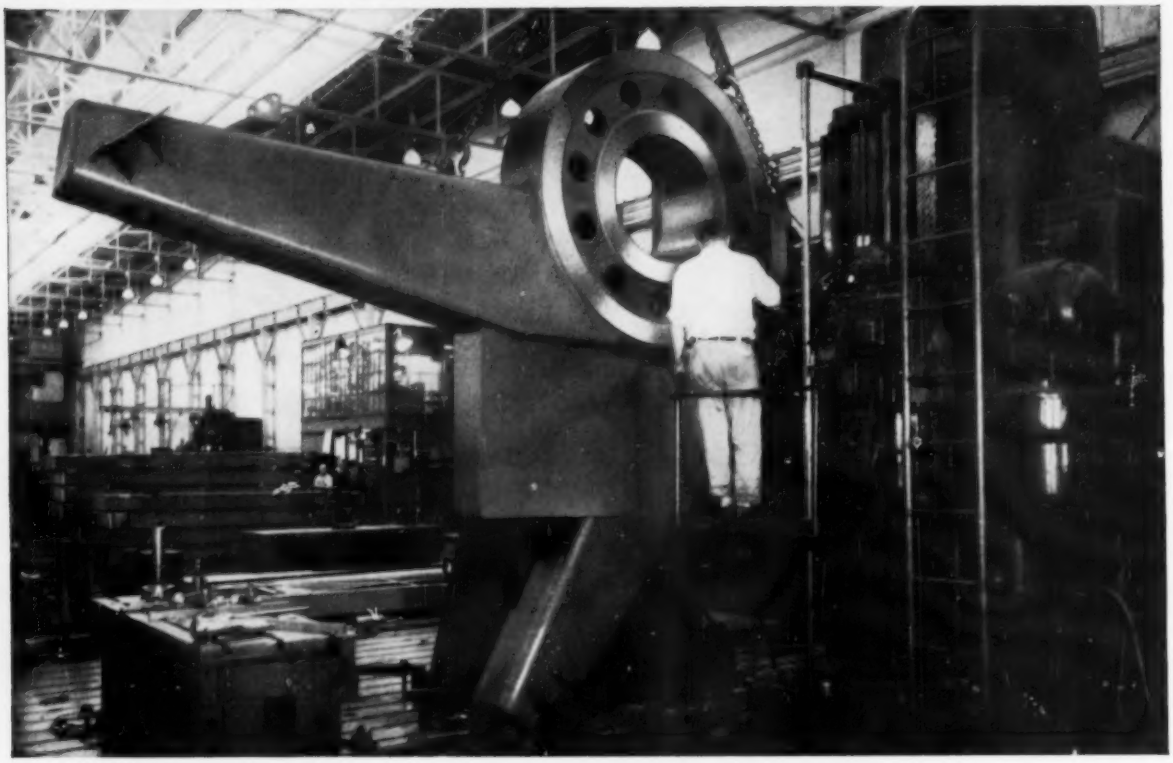

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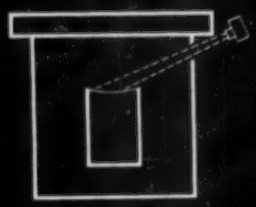

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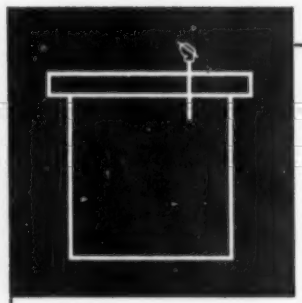
Honeywell has the tools to Solve your high-temperature



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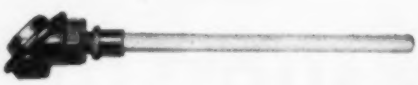
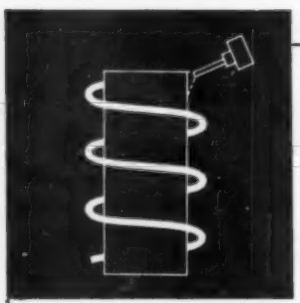
For sensing temperatures in the area of 4000°F.

New experimental Honeywell thermocouple materials like Rhenium-Molybdenum and Rhenium-Tungsten measure temperatures as high as 4000°F. Great diversity of elements, heads, extension wire, protecting tubes and accessories permits you to select the thermocouple which fits your application *exactly*.





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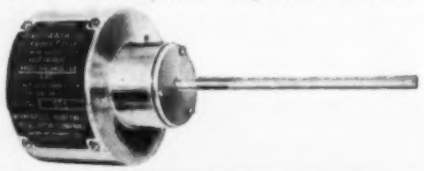
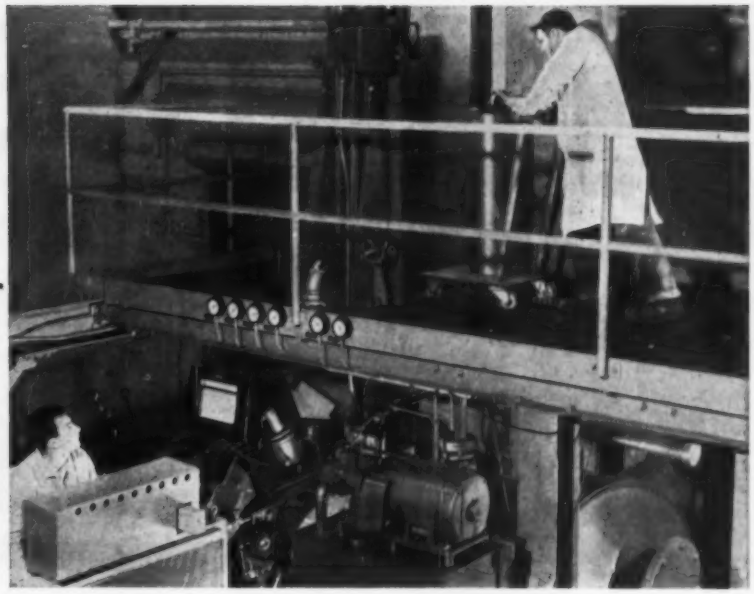
For measuring temperatures to 3600°F.

Sapphire rods are used as lens replacements in *Radiamatic* pyrometers. They provide accurate high-temperature measurement where such measurement previously could not be made by conventional means. For example, sapphire rod detectors can be inserted between the coils of an induction heater or "sight" on a target as small as ⅛" to deliver precise temperature indication.





CONTINUOUS MELT RECORD AT 3000°F with the *Radiamatic* unit (arrow) attached to a Stokes semi-continuous vacuum furnace at Allegheny Ludlum Steel Corporation, Watervliet (N.Y.) Works. Honeywell engineers worked with Allegheny-Ludlum to provide a constant record of vacuum furnace temperature—without calibrating rheostats or other complicated adjustments. The *Radiamatic* radiation pyrometer and engineering know-how solved this seemingly insoluble problem.

measurement problems

Precise measurement of high temperatures is almost an art. Working effectively with temperatures over 2800°F. calls for an intimate knowledge of materials and methods that can be gained only from broad experience. Through this experience—in every aspect of metal processing—Honeywell has developed special techniques and equipment for measuring high temperatures.

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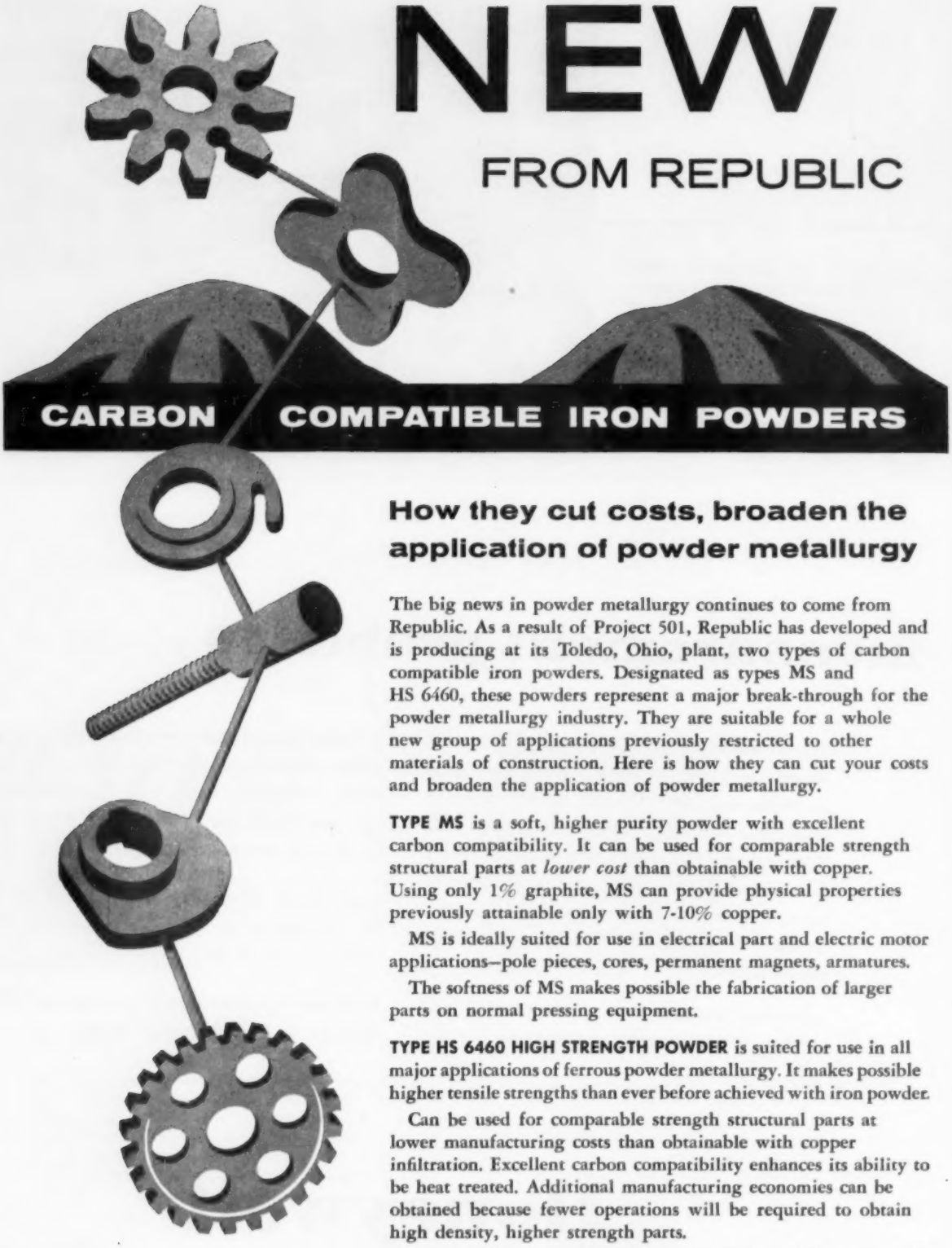

How they cut costs, broaden the application of powder metallurgy

The big news in powder metallurgy continues to come from Republic. As a result of Project 501, Republic has developed and is producing at its Toledo, Ohio, plant, two types of carbon compatible iron powders. Designated as types MS and HS 6460, these powders represent a major break-through for the powder metallurgy industry. They are suitable for a whole new group of applications previously restricted to other materials of construction. Here is how they can cut your costs and broaden the application of powder metallurgy.

TYPE MS is a soft, higher purity powder with excellent carbon compatibility. It can be used for comparable strength structural parts at *lower cost* than obtainable with copper. Using only 1% graphite, MS can provide physical properties previously attainable only with 7-10% copper.

MS is ideally suited for use in electrical part and electric motor applications—pole pieces, cores, permanent magnets, armatures.

The softness of MS makes possible the fabrication of larger parts on normal pressing equipment.

TYPE HS 6460 HIGH STRENGTH POWDER is suited for use in all major applications of ferrous powder metallurgy. It makes possible higher tensile strengths than ever before achieved with iron powder.

Can be used for comparable strength structural parts at lower manufacturing costs than obtainable with copper infiltration. Excellent carbon compatibility enhances its ability to be heat treated. Additional manufacturing economies can be obtained because fewer operations will be required to obtain high density, higher strength parts.

Our metallurgists and engineers are ready to help you utilize all the advantages of Republic Carbon Compatible Powders. Just mail the coupon to obtain their services, or for technical data sheets on Type MS and Type HS 6460 Powder.

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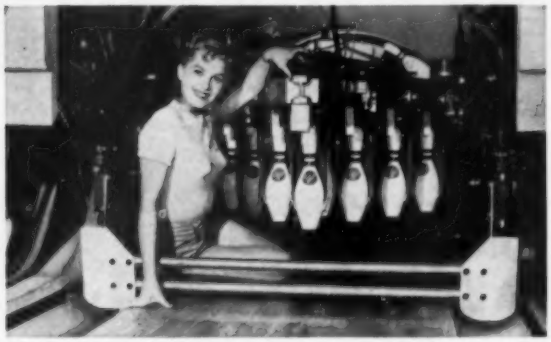
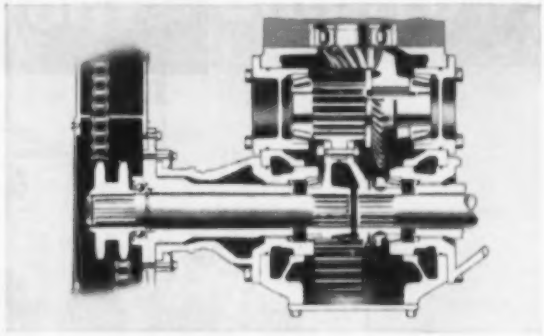
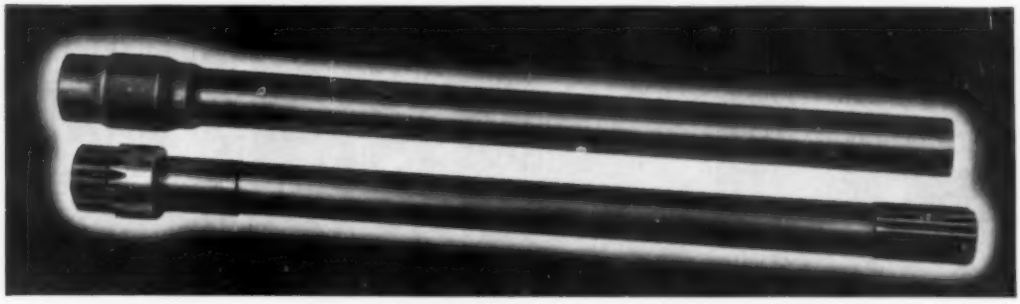


AMF CUTS COSTS, builds a better pinspotter with Republic ELECTRUNITE® Mechanical Tubing. On the initial order, ELECTRUNITE saved American Machine & Foundry Company, Brooklyn, New York, $34,000 in manufacturing their famous AMF Automatic Pinspotter. AMF was able to eliminate boring and grinding operations because ELECTRUNITE met O.D. tolerance requirements. This feature resulted in a savings of $15,000 in fabricating operations. Another $19,000 was saved on the cost of ELECTRUNITE as compared with tubing previously used. In uniformity, quality, original costs, Republic ELECTRUNITE Mechanical Tubing can save you time and money, too. Call Republic, or mail coupon for facts.



EXCEPTIONALLY HIGH STRENGTH-TO-WEIGHT RATIOS plus resistance to fatigue, stress, shock, and impact are values of Republic Alloy Steels that equipment builders have been relying on for years. Engineers and metallurgists of the Adams Division, LeTourneau-Westinghouse Company, for example, spent thousands of hours on research and testing of all types of steels to find one that would reduce ultimate fatigue to an absolute minimum in the drive axle of their "660" Motor Grader. They selected Republic Hot Rolled 4340 Alloy Steel. This fine steel not only resists fatigue, but also is able to take high torque without a permanent set. Specify Republic Alloy Steels where strength and toughness must resist heavy-duty roughness. Our metallurgists will help you.



NEW FABRICATING PROCESS MEANS ECONOMY. Ford Tractor power take-off counter-shafts cost less to produce using Republic Die-Form blanks, as compared with previous materials. Blank is shown on top . . . completed shaft below. Die-Form is a new method of cold forming hot rolled carbon, alloy, or stainless steel bars into multi-diameter blanks ready for final machining. Since Die-Form blanks closely approximate the completed part, final machining is minimized. Handling costs for raw material and scrap disposal are reduced—production rates increased. Die-Form Process improves machinability of any given steel analysis. Permits further savings through use of higher feeds and speeds. Mail coupon for complete facts.

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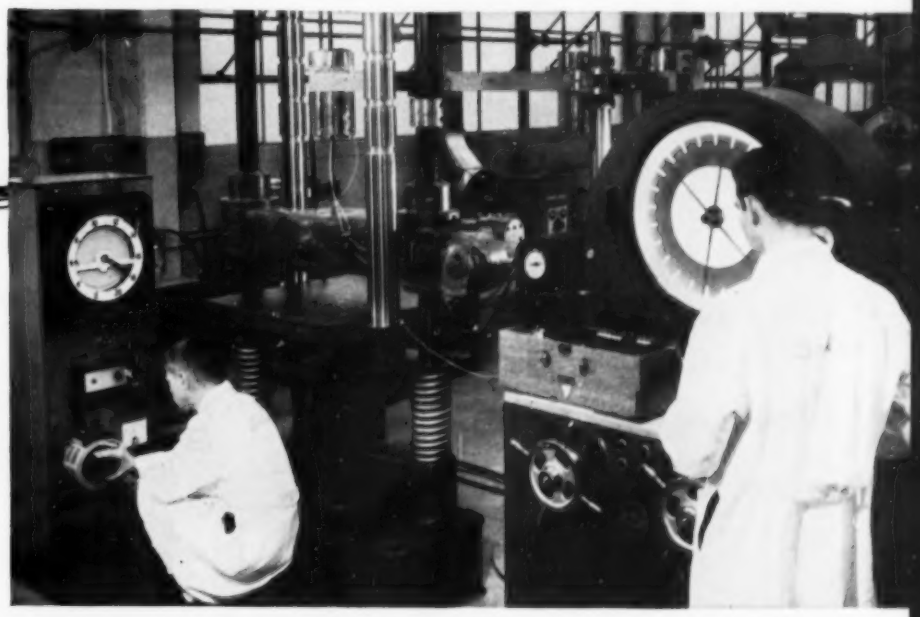
THE steels for the products and designs you're planning for tomorrow are being perfected today—here in the Timken Company's new Metallurgical Research Center. We use the newest, most modern facilities ranging from an experimental melting laboratory and an X-ray spectrometer to one of the industry's finest technical libraries to study and evaluate new steel compositions—solve customer problems. For example, in our new Vacuum Fusion Laboratory (shown above) new steels are analyzed for impurities present in minute quantities.

Work like this developed the Timken Company's "16-25-6" steel, the steel that helped keep jets flying—now helps get missiles off the ground. For the steels you'll need or the steel problems you may have, call upon our experts for help. They've been developing new steels and solving hundreds of tough steel problems for 30 years. Call or write the leaders in electric furnace fine alloy steel production, The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steels and Removable Rock Bits.



THIS HOT TENSILE TESTING MACHINE tests steel under increasing loads (as high as 60 tons) at high temperature, until rupture occurs. Here steels are pretested to determine their performance in high temperature applications. This new laboratory is the latest example of Timken Company pioneering in fine alloy electric furnace steels.

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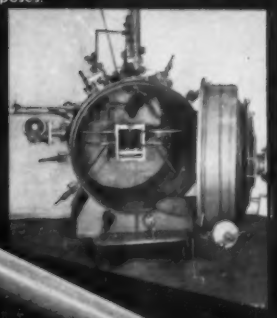

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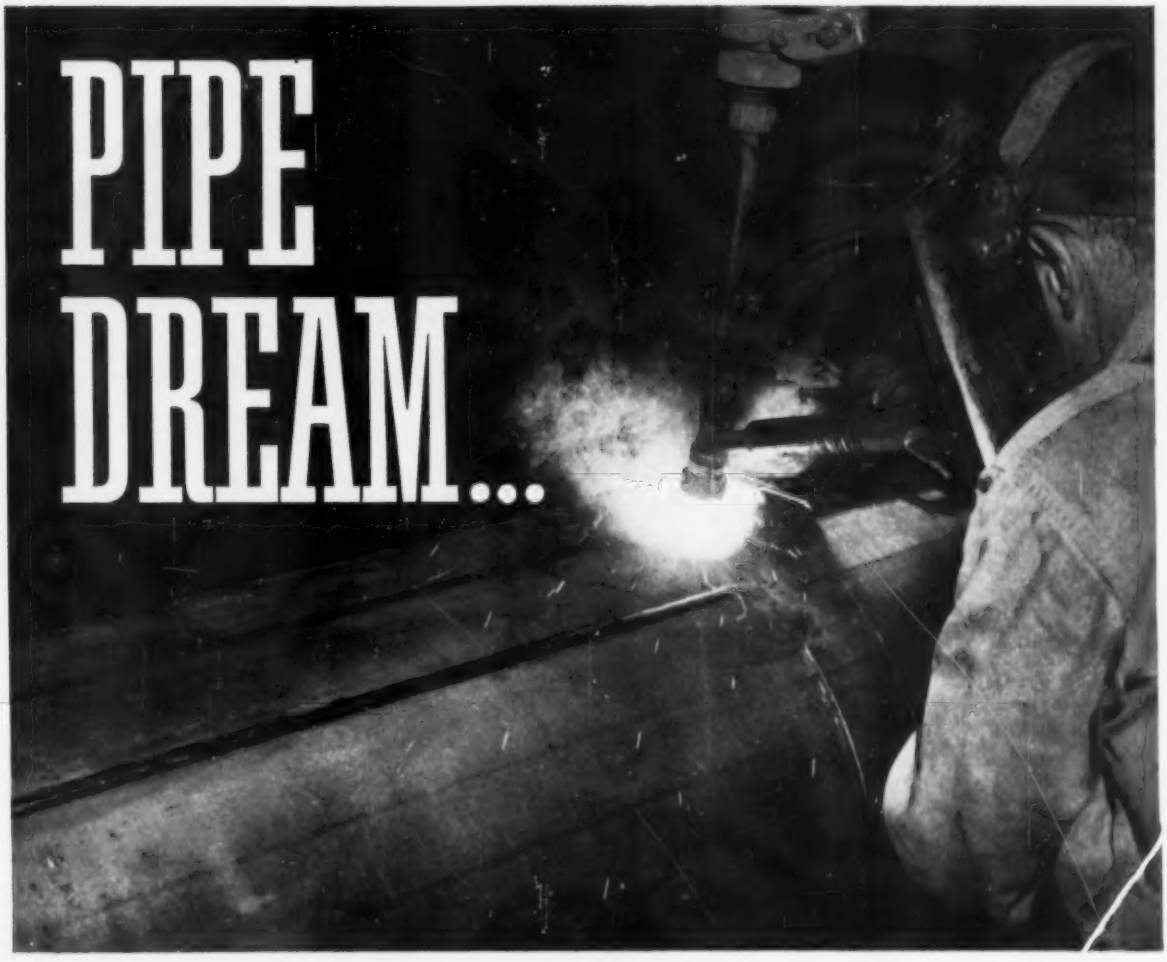

...UNIONARC Welding saves $7000 on one production run

UNIONARC Welding—LINDE's new electric welding method for steel—increased production by 300% and saved a western pipe mill $7000 on a single run of steel pipe. Replacing covered electrode methods, UNIONARC Welding is expected to save this company $150,000 a year.

UNIONARC Welding uses a continuously-fed wire electrode, magnetically coated with flux and shielded with carbon dioxide gas. It has three times the speed and weld penetration of covered electrode welding. And UNIONARC Welding gives you "finished", X-ray quality welds and low hydrogen deposits—in all welding positions.

See for yourself—ask your nearest LINDE representative to *prove* that UNIONARC Welding slashes time and labor costs over conventional methods. Call your local LINDE office today! Or write Dept. MD4, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in other principal cities. In Canada: Linde Company, Division of Union Carbide Canada Limited.

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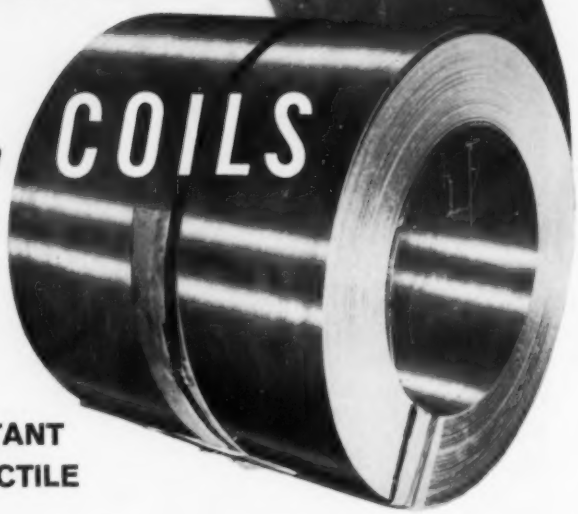

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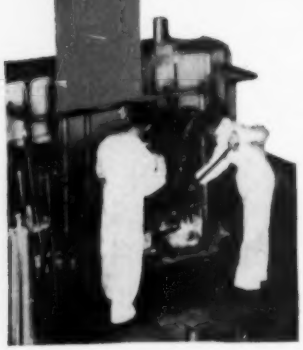

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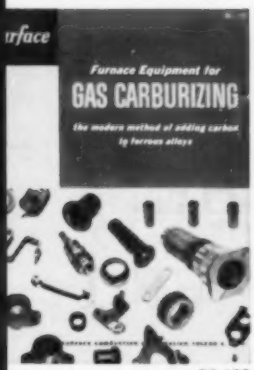

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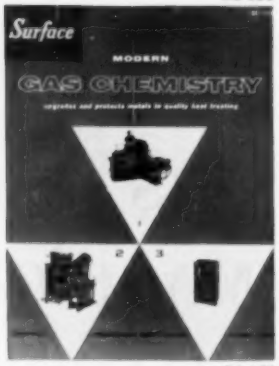

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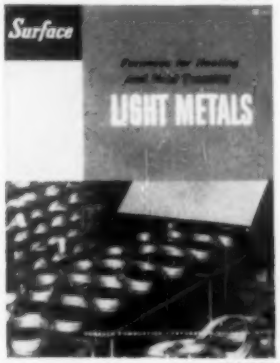

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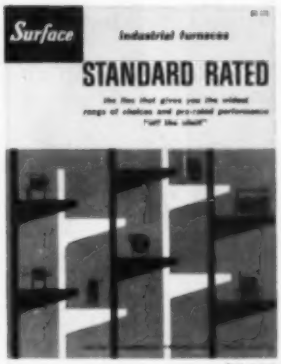

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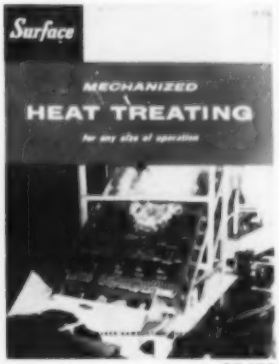

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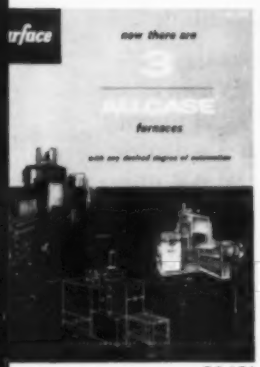

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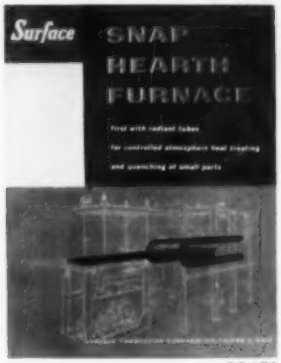

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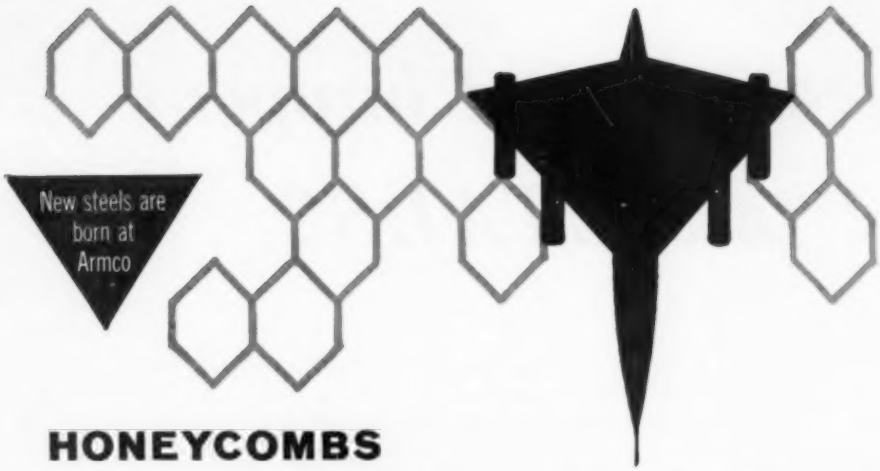

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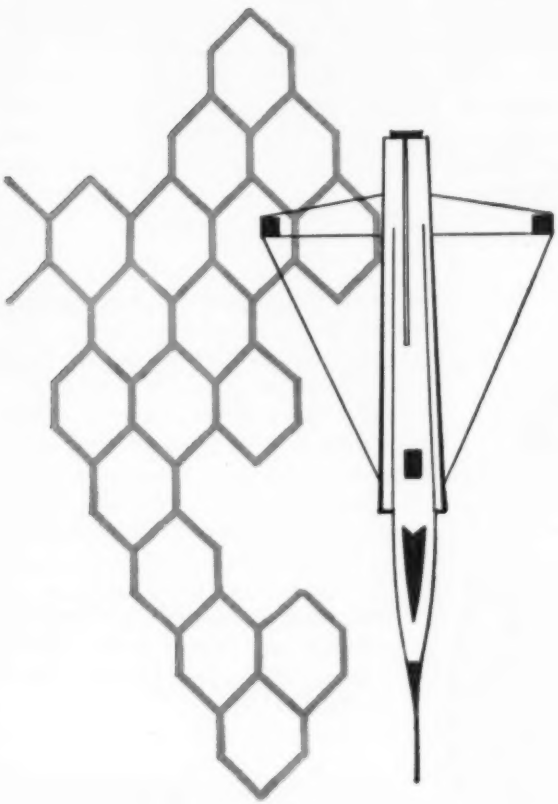

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Dr. Ralph Leiter, for example, Director of Laboratories at Philadelphia headquarters of The Budd Company, metalworking fabricators of components and end-products for the railroad, automotive, aircraft, missile and atomic energy industries.

Together with his staff of engineers and metallurgists—metals engineers—Dr. Leiter has been active in such diverse areas as developing alloys for Budd railway disc brakes; determining the best mass production forming and welding processes for auto bodies, chassis, wheels and brakes; and selecting, testing, forming, fabricating and heat-treating high temperature parts for missiles, rockets and jet engines. A major achievement is their development of a resistance-welded stainless steel corrugation-reinforced and sandwiched structure called "Integrated Core Panel", now being applied to a critical nuclear program and under test for supersonic aircraft for its high strength-to-weight ratio and resistance to heat.

By the very nature of their jobs, these men are fundamentally concerned with specification and purchasing decisions affecting metals. They are part of a larger group of 30,000 metals engineers across the nation whose job it is, similarly, to care what happens to metals—to take an influential interest in metals selection, processing, fabrication, etc. METAL PROGRESS anticipates their needs. They learn from it . . . depend on it . . . contribute to it. Reason enough that METAL PROGRESS is *also* your best advertising approach to this vital market in 1959.

Dr. Leiter heads an extensive staff of metals engineers. Here he inspects a forged and butt-welded compressor ring of a Pratt & Whitney Aircraft J57 turbo-jet engine with Chief Metallurgist Charles B. Allen (L) at Budd's Red Lion Plant.

Marjorie R. Hyslop
Managing Editor

DISCUSSING
◀ a stamped, formed and fusion-welded high temperature jet engine component currently under manufacture at Budd.

INSPECTING
a disc-type brake on the truck of a Budd-designed RDC self-propelled Rail Diesel Car. ▶

EXAMINING
◀ a Sciaky Modu Wave Machine roll-welding operation on a Pratt & Whitney Aircraft engine afterburner.

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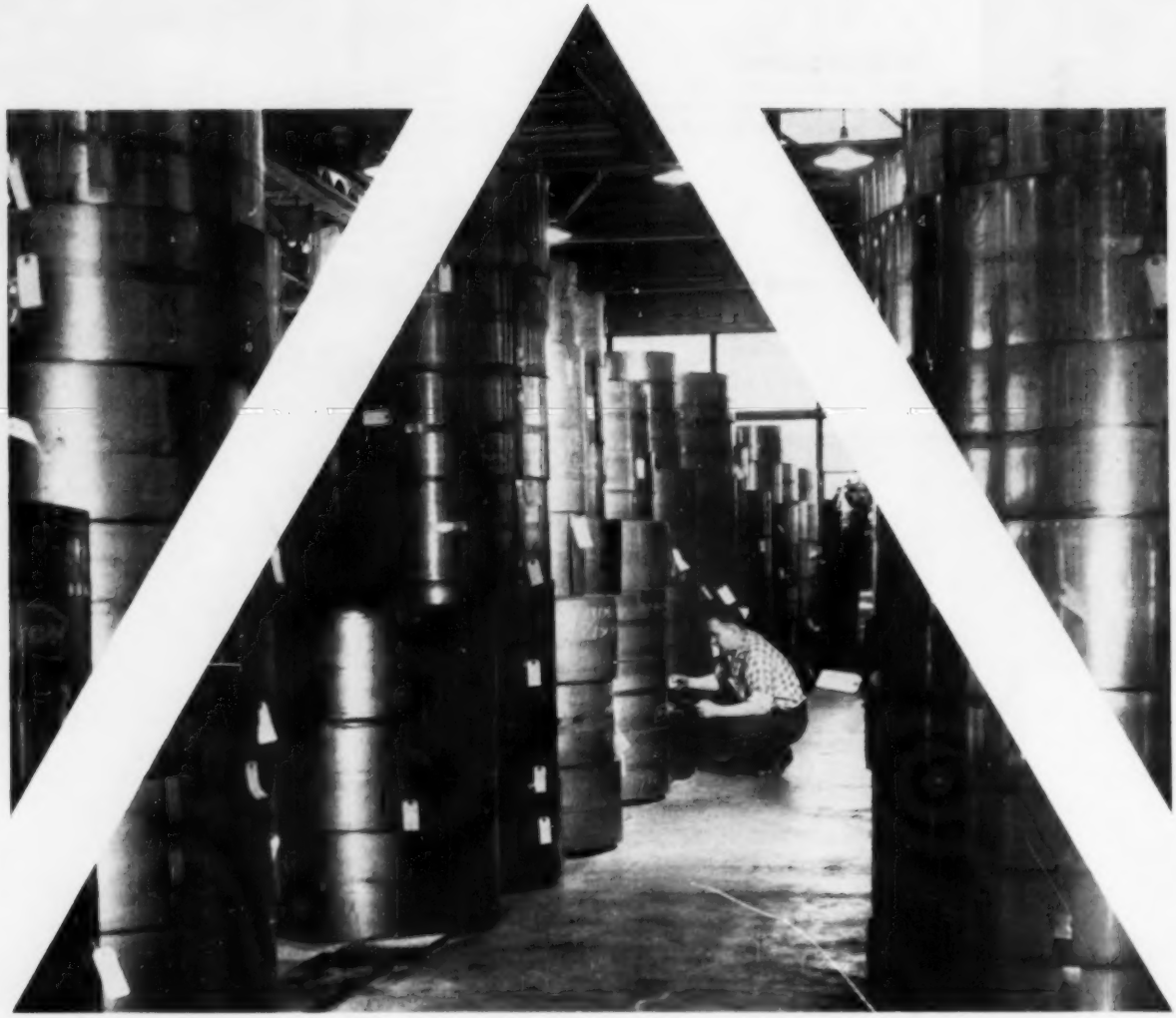

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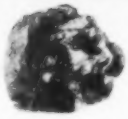

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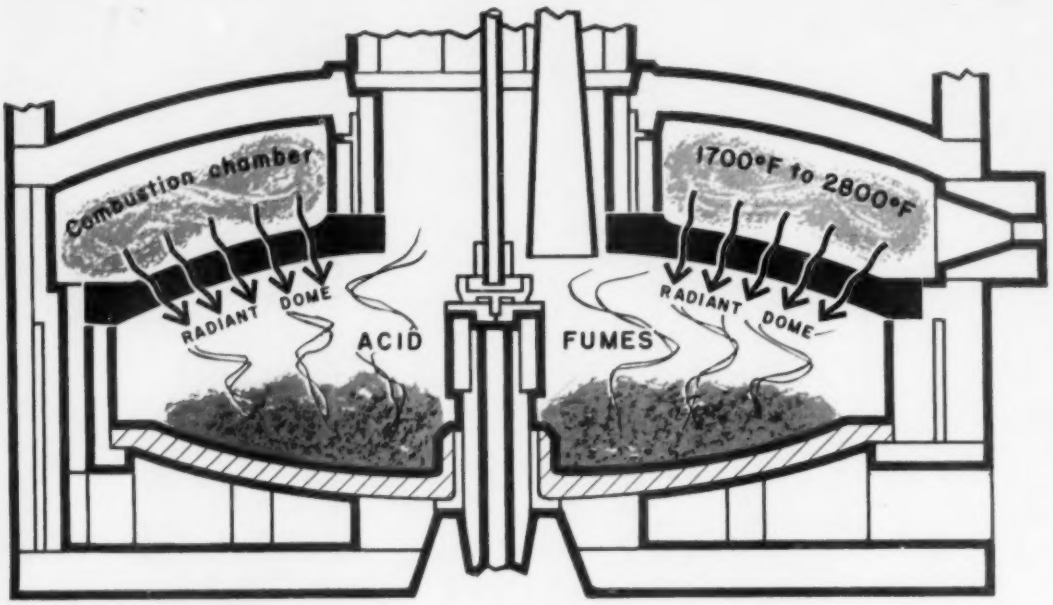

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A radiant dome is used for indirect heating in the Mannheim furnace sketched above. Sulfuric acid and salt cake are fed into an externally heated chamber to produce HCl gas. Temperatures above the radiant dome range from 1700–2800 F.

The problem here is complete separation of the highly corrosive charge from the heat source by a material that can live with these destructive conditions, yet, will transmit heat very rapidly. The problem is intensified because the dome may be as large as 20′ in diameter, hence must be constructed of a material with adequate strength even at extreme temperatures.

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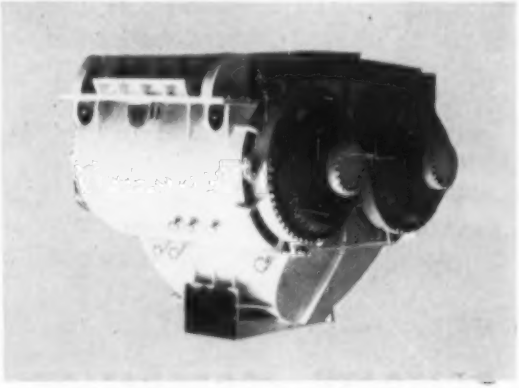

These twin condenser units were designed and built by Allis-Chalmers. Bridgeport tubes were used throughout.

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Written by Members of the Philadelphia Chapter
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Edited by G. William Zuspan
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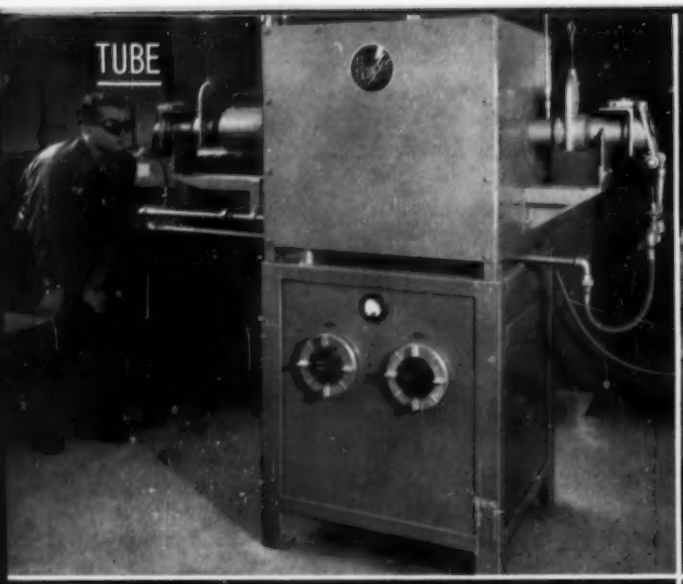

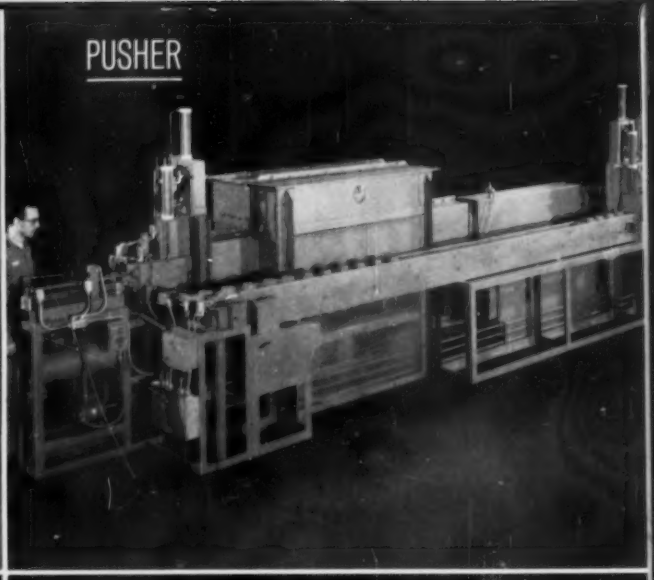

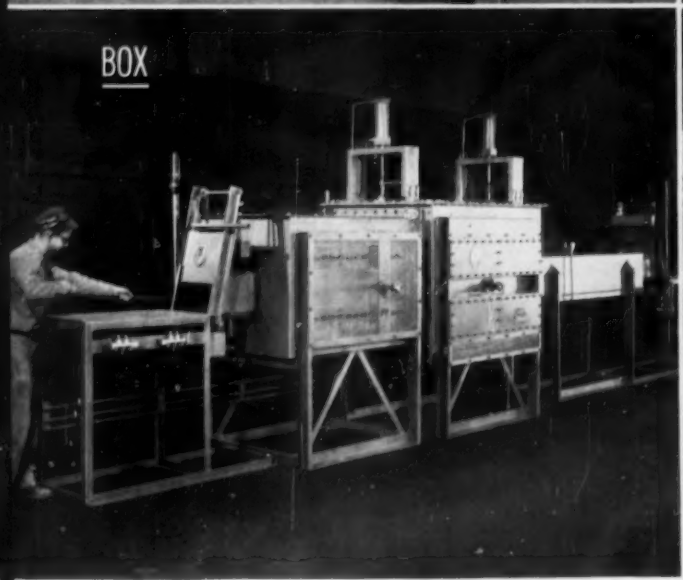

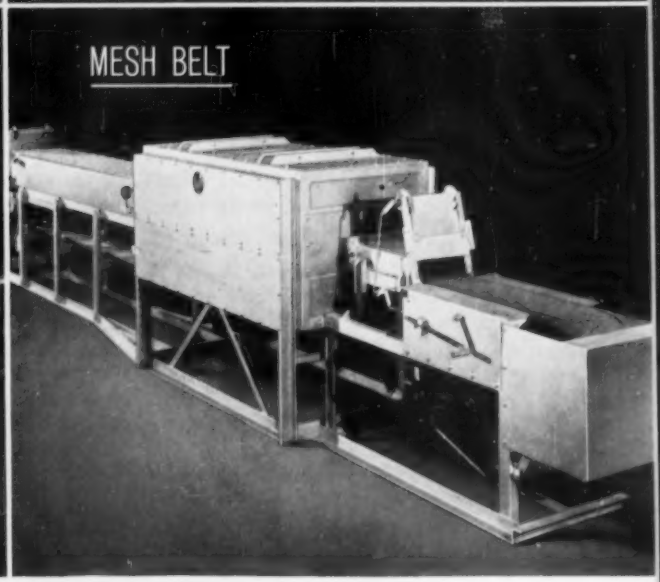

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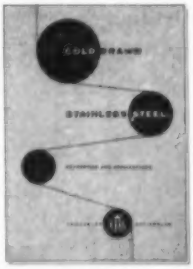

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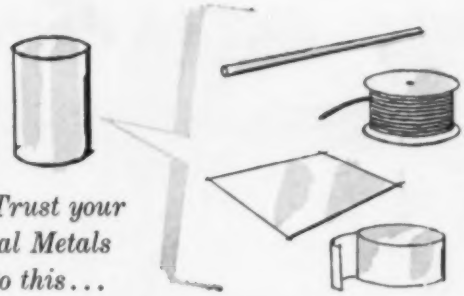

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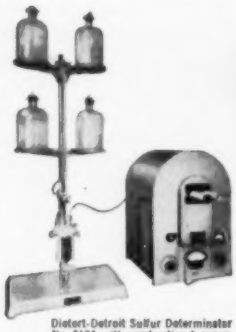

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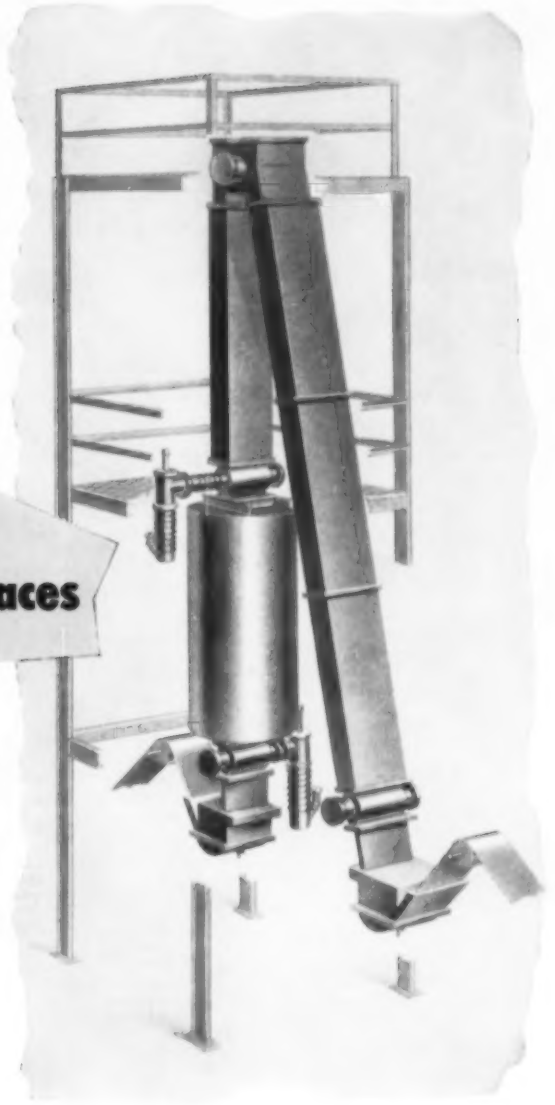

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Beryllium, Hafnium, Tantalum, Titanium, Zirconium, High Carbon Steels, 200—300—400 and Precipitation Hardening Stainless Steels

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Again Electric Furnace Co. research scores an important break-through in heat processing. Now, fully developed and ready for commercial service, these new EF continuous vacuum furnaces offer many advantages. This continuous vacuum treatment:—

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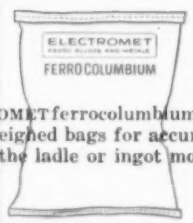
The effect of columbium in improving the strength and weldability of mild carbon steels was discovered in 1936 by UNION CARBIDE METALS (U. S. Patent No. 2264355). This discovery was made available to the steel industry. Now, long-standing government restrictions on using columbium have been removed. Columbium is in plentiful supply. New ore sources and refining processes have been found.

UNION CARBIDE METALS is therefore conducting a further extensive evaluation of columbium-treated steels. Results of this continuing investigation will also be made available to the steel industry. For information on columbium, contact UNION CARBIDE METALS, pioneer in the production of highly soluble, high-purity ferrocolumbium since 1935.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.



ELECTROMET ferrocolumbium is offered in pre-weighed bags for accurate additions to the ladle or ingot molds.

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